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NASA Technical Memorandum 78751

SEASAT-A SATELLITE SCATTEROMETER (SASS) VALIDATION AND EXPERIMENT PLAN

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Edited by Lyle C. Schroeder

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SeaSat-A Satellite Scatterometer

(SASS)

Validation and Experiment

Plan

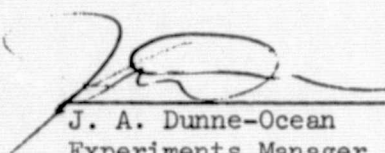
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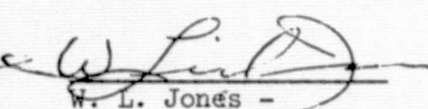
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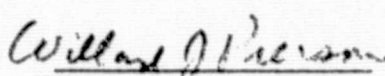
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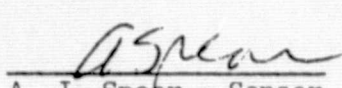
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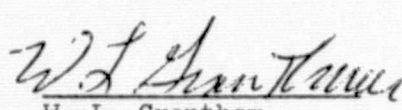
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1.0 SCOPE

This plan has been generated by the SeaSat-A Satellite Scatterometer (SASS) Experiment Team to define the pre and post-launch activities necessary to conduct sensor validation and geophysical evaluation. Details included are an instrument and experiment description/performance requirements, success criteria, constraints, mission requirements, data processing requirement and data analysis responsibilities.

It is intended that this plan be updated as required to reflect the evolving nature of the Experiment. Proposed changes to the plan shall be submitted to the SASS Experiment Team in care of Dr. W. Linwood Jones (LaRC) for team discussion and consensus, and shall be implemented as addendums only after formal approval/concurrence by the signatories to the document.

2.0 APPLICABLE DOCUMENTS

REFERENCE	EXP. PLAN SECTION
1. Scatterometer (SASS)/Satellite System Interface Control Document SeaSat-A LMSC-D 940728 Rev. A, August 1976.	4.2
2. Grantham, et al, "An Operational Satellite Scatterometer for Wind Vector Measurements Over the Oceans," NASA TMX 72672, March 1975.	5.0
3. Grantham, et al, "The SeaSat-A Satellite Scatterometer,": IEEE J. Oceanic Eng., April 1977.	5.8, 6.0, 7.2.2.4, 9.4.1.3
4. Jones, Schroeder, and Mitchell, "Aircraft Measurements of the Microwave Scattering Signature of the Ocean", IEEE Trans. Antennas Propagat./IEEE J. Oceanic Eng. (Special Issue on Radio Oceanography), Jan. 1977.	5.8
5. Wilkerson, "NOAA-SeaSat-A, Catalog of Potential Platforms for In situ Data Collection", March 1978	7.1

REFERENCE	EXP. PLAN SECTION
6. Ernst, "NOAA-SeaSat-A Program for Oceanic Surface Winds," NOAA Tech. Memo NESS xxx (TBD).	7.1
7. SASS Engineering Assessment Plan, NASA-LaRC	7.2
8. Project Plan for SeaSat-A 1978 Mission JPL 622-3, April 1977.	7.2
9. Cook, et al, "Measurement of Microwave Antenna Patterns from an Orbiting Spacecraft," Proc 1974 Int. IEEE/ AP-S Symp Digest, Atlanta, GA, June 1974, IEEE Publ. 74 CHO-857-3 AP, pp. 51-53.	7.2.2.4
10. SeaSat-A - SDR Detail Functional Specifications.	10.0
11. SASS Sensor Implementation Plan, NASA LaRC, October 1976.	11.1

SYMBOLS & DEFINITIONS

Team	SASS Experiment Team
Project	SeaSat-A Project Management (JPL)
u_*	Friction velocity vector [cm/s, deg]
NRCS, σ^0	Normalized radar cross section
SASS	SeaSat A Satellite Scatterometer
SAR	Synthetic Aperture Radar
SMMR	Scanning Multifrequency Microwave Radiometer
ALT	Altimeter
VIRR	Visible and Infrared Radiometer
FNWC	U.S. Navy Fleet Numerical Weather Central
JPL	The Jet Propulsion Laboratory
TBD	<u>To Be Determined</u>

LaRC	NASA Langley Research Center
SDR	Sensor Data Record
ADF	Algorithm Development Facility
IGDR	Interim Geophysical Data Record
GISS	Goddard Institute for Space Sciences
$\vec{U}_{19.5}, \vec{U}_{10}$	Neutral stability vector winds at 19.5 and 10 meter height [m/s, deg]
NOAA	National Oceanic and Atmospheric Administration
SUS	SeaSat Underflight Scatterometer
NMC	National Meteorological Center
NESS	National Environmental Satellite Service
NEPRF	Naval Environment Prediction and Research Facility
NWS	National Weather Service
CUNY	City University of New York
U of K, KU	University of Kansas
GPCF	General Purpose Computer Facility (JPL)
Z_o	Roughness length as used in planetary boundary layer models over the ocean [cm]

3.0 EXPERIMENT OBJECTIVES

3.1 General

The general objective of the SASS experiment is to demonstrate the utility of microwave scatterometry for the remote sensing of certain physical characteristics of ocean and land surfaces. The specific objectives are listed below under primary and secondary categories. These objectives have been so arranged because of NASA/SeaSat-A Project priorities only and therefore are subject to modification by SeaSat-A users depending upon their particular interest.

3.2 Primary Objectives

3.2.1 To deduce the synoptic scale wind vectors¹ and u_* (friction velocity vector) over the world's ocean. The neutral stability ocean surface-wind measurement shall achieve the following specifications (reference 1):

- (1) Range and Accuracy (1 σ value)
 - (a) Wind speed - 4m/s to > 24 m/s, ± 2 m/s
or $\pm 10\%$ whichever greater
 - (b) Wind direction - 0° to 360° , $\pm 20^\circ$
- (2) Ocean Coverage
 - (a) Width - ≥ 1000 km (total swath - both sides)
 - (b) Cell resolution - ≤ 50 km
 - (c) Measurement sampling - $100 \text{ km} \times 100 \text{ km}$
(along track $\times$ cross track, measurement centers)

3.2.2 To obtain normalized radar scattering coefficient (NRCS, σ^0) measurements in the ocean over a wide variety of wave and weather conditions to compare with actual friction velocity and wind vectors measured in the atmosphere boundary layer, and to study factors that may affect these measurements such as

- (1) Large scale gravity ocean wave characteristics
- (2) Air and sea temperatures (atmospheric stability)
- (3) Tides and ocean currents
- (4) Rain and humidity
- (5) Clouds
- (6) Sea ice
- (7) Floating vegetation

¹10.0 m and 19.5 m neutral stability wind vector - see Section 7.1 for discussion.

3.2.3 To demonstrate the capability to use data from other sensors and sources to make atmospheric and cloud liquid water attenuation corrections to scatterometer measurements.

3.3 Secondary Objectives

3.3.1 To demonstrate the potential for nearly all-weather, day-night capability for wind determination over the oceans in an operational mode for use in numerical weather and wave forecast models.

3.3.2 To obtain radar scattering coefficient measurements over land for:

- (1) Continental ice/snow coverage
- (2) Ice type identification
- (3) Water resources survey
- (4) Vegetation
- (5) To prepare a catalog of NRCS for various surfaces for design of future radar systems (such as a Space Shuttle SAR).

3.4 Experiment Rationale

3.4.1 Ocean Applications

The SASS experiment is to make measurements of radar backscatter over the oceans on as nearly a continuous basis as possible and to use these and other data to obtain estimates of the winds in the surface layer of the planetary boundary layer. The SMMR and the VIRR data will be merged with data from the SASS to correct the backscatter values for atmospheric and cloud liquid water attenuation. These corrected backscatter measurements will be processed to yield estimates of friction velocity and the 10 m and the 19.5 m neutral stability vector winds over approximately a 500 km swath along each/both side(s) of the satellite subtrack. One of the possible relationships

between $\vec{u}_*$ and $U_{19.5}$ or U_{10} implied by the choice of a relationship between Z_0 and $\vec{u}_*$ will be selected. Enough information will be provided so that other theories can be used to calculate different values of $\vec{u}_*$. The low-rate sensor (SASS, SMMR, and VIIR) raw data can be processed at several facilities. First, to utilize these SeaSat-A sensors in a real-time demonstration, data that is less than 6 hours old when received will be processed by the U.S. Navy Fleet Numerical Weather Central (FNWC). The Project will also process a limited subset of these low-rate sensor data for the Experiment Teams to evaluate the sensor performance, the theoretical models, and the geophysical measurement. Later after the sensor and geophysical algorithms have been validated the Project will archive satellite data for scientific investigation.

3.4.2 Land Applications

The SASS experiment is to make simultaneous measurements with the SMMR and/or the SAR while over land and ice on a near continuous basis as possible. Simultaneous measurements with SAR and SMMR will aid in the inference of geophysical parameters for the surface scene. The analysis of combined SASS/SMMR data will yield improved results over each data set taken separately. The SASS geophysical data processing for overland usage will be to scattering coefficient only and will be provided by the Project.

4.0 CONSTRAINTS

4.1 General

It is recognized that the main purpose of the SASS Experiment on the SeaSat-A satellite is to prove the concept of the scatterometer as a viable remote sensor of ocean surface winds. It is important to emphasize that the

quality of the data is not to be compromised, and that any hardware and facility tradeoffs be made so as to maximize the capability to explore all the potential applications of the system.

4.2 Instrument (Ref. 1)

The Team assumes that the instrument is operated as specified in other Project documentation, or the data shall be so identified. The following is a list of key constraints imposed to insure good data quality. Additional constraints are listed in the Interface Control Document (Reference 1).

4.2.1 Orbit Constraints

Semimajor axis	7140 - 7213 km
Eccentricity	0 - .002
Argument of Perigee	70° - 110°
Inclination	104° - 108°
Longitude of Ascending node	0° - 360°

4.2.2 Attitude Constraints (3 std. dev.)

	Control Boundary	Determination
Roll	$\pm 0.35^\circ$	$\pm 0.20^\circ$
Pitch	$\pm 0.35^\circ$	$\pm 0.20^\circ$
Yaw	$\pm 0.80^\circ$	$\pm .8^\circ$

Additionally, a special azimuth rotation maneuver is required for sensor validation as described in Section 7.2.2.1.

4.2.3 Instrument Turn-on Time Delay and Temperature Range.

SASS standby to operate	3 minutes
SASS off to operate	10 minutes

(Assumes spacecraft regulated bus is ON).

The SASS shall not be turned on unless the baseplate temperature is in the range -10 to 55 C.

4.2.4 Maximum Length of Time in Stand-by

This period should not exceed 4 hours.

4.3 Constraints due to Sensor Validation and Geophysical Evaluation

4.3.1 Definition of when instrument is to be ON.

In general, the SASS sensor is required to be on over all ocean passes, and over land where possible, and whenever SASS is on, certain simultaneous VIRR, ALT, and SMMR data are required. (See Section 4.3.4.)

If during certain periods of the mission, the spacecraft will be power limited and will require that the SASS be operated at a duty cycle less than 100 percent, the decision of when to turn-on/turn-off the SASS shall be based on the earliest/latest time that any Doppler cell totally views the ocean. In addition, the instrument turn-on time delay given in Section 4.2.3 must be taken into account. If the "regulated bus on" assumption is not satisfied, 30 additional minutes must be added for SASS stabilization.

Furthermore, certain operations involved in sensor validation (Section 7.2.2 through 7.2.2.5) and geophysical evaluation (Section 7.2.3 to 7.2.3.5) require the Project to provide for aircraft underflights, gathering and storing surface truth data, obtaining simultaneous data from other SeaSat-A sensors, and processing data in certain ways. Section 9.2 defines the coordination scheme for conducting post-launch operations. The following elaborates on these constraints.

4.3.2 Aircraft Underflight Requirement Constraints

The project shall provide for underflights of SeaSat-A using a suitably instrumented aircraft. The justification of these underflights are given in Section 7.1, section 7.2.2.1 gives specifics on sensor validation tasks using aircraft scattering coefficient data, while 7.2.3.4 describes

evaluation tasks using aircraft data. Methods of working out details of conducting these operations are discussed in Section 9.2.

4.3.3 Surface Truth Requirement Constraints

The project shall coordinate the gathering of "surface truth" data necessary for conducting sensor validation and geophysical evaluation tasks. Sections defining the need and type of surface truth are: Primary 10.2.4.2; Secondary 7.1, 7.2.2.2, 7.2.2.4, 7.2.3.1, 7.2.3.2, 7.3.

4.3.4 Simultaneous Data From Other Sensors

The project shall coordinate the gathering of data from other on-board sensors which are necessary to conduct sensor validation and geophysical evaluation tasks. Sections defining the needs and type of data from other sensors are: Primary source 10.2.4.1; others, 7.1, 7.2.2.3, 9.4.1.2, 9.4.1.3, 10.2.1.

4.4 Data Processing Constraints

The project shall coordinate all data processing of the SASS and other required data. The general processing requirements are defined in Section 9.4.1, and the SDR, ADF, and IGDR requirements are specified in Sections 9.4.1.1, 9.4.1.2, and 9.4.1.3, respectively. Data to be provided to FNWC and to GISS are identified in Sections 9.4.1.4 and 7.2.3.3. Digital, false color and auxiliary data are defined in Sections 10.2.2 through 10.2.4.

5.0 INSTRUMENT PERFORMANCE REQUIREMENTS (Ref. 2)

5.1 General

In order to achieve the experiment objectives, the following key instrument performance parameters have been established: frequency, polarization, resolution cell size, distance between measurements, swath width,

dynamic range, accuracy, and spatial resolution. The definitions of these parameters and the respective requirements placed on them are addressed in this section.

5.2 Scatterometer Frequency

The scatterometer will transmit at a frequency of 14.599270 GHz and receive at frequencies nominally shifted by as much as 400 kHz for the 15 Doppler resolution cells.

5.3 Polarization

The instrument is capable of making both vertically and horizontally polarized measurements of scattering coefficient σ^0 over the full swath width with the exception that only vertical polarization data will be valid for the near nadir secondary swath 140 km wide. Horizontal polarization data will be taken for the near nadir swath but reduced antenna gain will mean less accurate data. The antenna polarization purity will be sufficient to avoid interference that would be present otherwise.

5.4 Resolution Cell Size

Each measurement over the primary swath (defined in section 5.6) shall be contained within a resolution cell nominally 50 km by 50 km. Secondary swath width (see section 5.6) cell size shall be allowed to exceed a 50 km square.

5.5 Distance Between Measurements

The instrument shall repeat σ^0 measurements periodically such that the separation on the earth's surface between measurements will be 100 km or less.

5.6 Swath Width - (See figure 1)

(1) Primary - As a primary requirement, σ^0 measurements shall be made over two swaths, each 500 km wide, extending from approximately 200 km to 700 km on either side of the subtrack.

(2) Secondary - There are three secondary swath regions. The first is 140 wide km swath measurement zone centered along the subtrack to obtain data near nadir for a better understanding of surface roughness on σ^0 . In addition, the other two provide σ^0 measurements on both sides of the satellite subtrack at angles greater than 55° to provide high wind speed data only.

5.7 Dynamic Range

The required wind speed measurement range is 4 m/s to 24 m/s over the primary swath. The inner and outer edges of the primary swath correspond to earth incidence angles of approximately 25° and 55° respectively. At incidence angles less than 25° the dependence of σ^0 on wind speed diminishes, and the accuracy requirements placed on the σ^0 measurement to achieve wind speed measurements with small enough errors are beyond the state-of-the-art. The outer angle of the primary swath is limited to about 55° since low level return signals at larger angles do not allow wind speed measurements below about 12 m/s. The instrument dynamic range required to satisfy the primary performance requirement is approximately 45 dB.

5.8 Accuracy

User generated wind speed accuracy requirements have been transformed to σ^0 measurement accuracy using empirically derived relationships between σ^0 and wind speed for SeaSat-A incidence angles (Details of this transformation are given in reference 3). The scatterometer is designed to

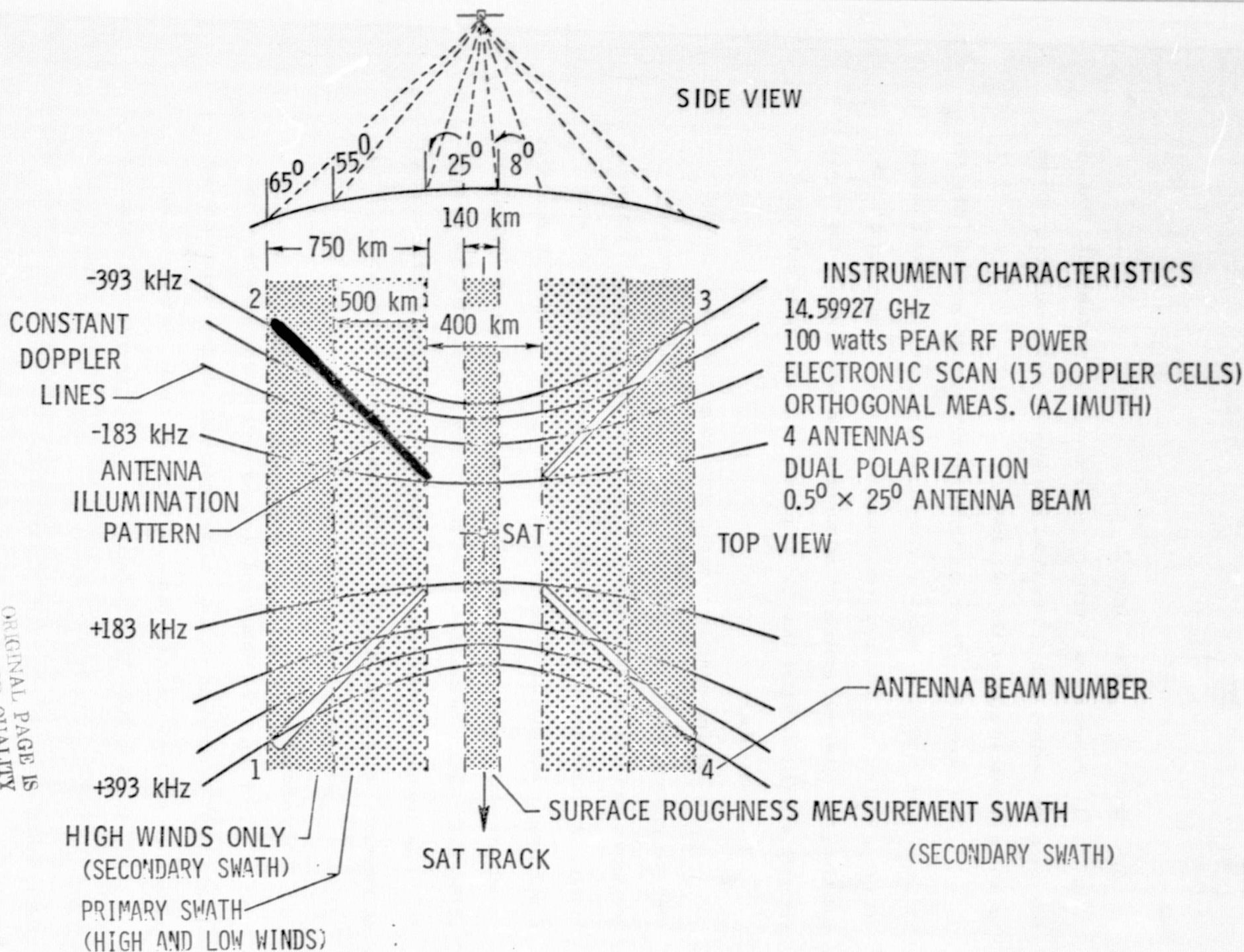


FIGURE 1.- SEASAT SCATTEROMETER CHARACTERISTICS

measure primary swath wind speeds to an accuracy of $\pm 2\text{m/s}$ or ± 10 percent, whichever is greater. The wind direction measurement accuracy goal is $\pm 20^\circ$.

An error budget was initially developed for the scatterometer (fig. 2, Table I) that must be satisfied in order to meet wind speed error requirements on the primary swath. To maintain these requirements within acceptable boundaries, constraints are imposed on the spacecraft attitude system, antenna squint prediction model, aircraft underflight instrument accuracy, and SASS electronics accuracy. Periodic reviews of these error sources are held to update SASS performance predictions. A copy of the performance predictions presented at the June 6-7, 1977 LaRC Comprehensive Review is given for σ° and wind speed on Tables II and III.

6.0 INSTRUMENT DESCRIPTION (Ref. 3)

A summary description of the SASS is given below. Further information is available in reference 3. A block diagram of the SASS is shown in figure 3. A frequency synthesizer generates the RF signals for the transmitter, mixers, and scatterometer processor, thus assuring coherency throughout the sensor. The low-level microwave output of the synthesizer is amplitude gated to insure high isolation (typically ≥ 60 dB) between the "ON" and "OFF" states. The pulsed rf is then amplified in the final output stage by a traveling wave tube amplifier. The 100W peak power output pulse is directed to the antennas through a series of waveguide components, circulators, and a 1×8 waveguide switching matrix. Each antenna has two ports, one for each polarization, which is switched in a preset fashion by the timing and control electronics.

Received RF energy from the proper antenna is directed through the eight-way switch, the T/R circulator, and receiver protection circulator

SASS ERROR SOURCES

$$\sigma^0 \text{ TOTAL ERROR}^* = \left(\sigma_A^2 + \sigma_s^2 + K_p^2 \right)^{1/2} + \sigma_B$$

σ_A - ANGULAR ERROR
 SPACECRAFT ATTITUDE UNCERTAINTY
 ANTENNA SQUINT UNCERTAINTY

σ_B - BIAS ERRORS
 INSTRUMENT (± 0.5 dB)
 RAIN

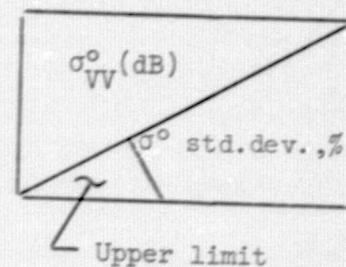
σ_s - INSTRUMENT RANDOM ERROR (± 0.1 dB)

K_p - RECEIVER COMMUNICATION NOISE ERROR

* Tables I, II, and III were developed assuming σ_B to be a random error rather than a bias error.

Table I.- σ^0 Accuracy Requirement

Incidence angle Wind* speed m/sec	25°	30°	40°	50°	55°
4	-16 86 50%	-21 118 50%	-24 113 50%	-27 113 50%	-28 109 50%
6	-14 55 50%	-18 70 50%	-21 74 50%	-23 74 50%	-24 74 50%
12	-9 29%	-12 35%	-15 32%	-18 32%	-19 32%
24	-4 18%	-6 20%	-9 20%	-12 20%	-13 20%
48	0 18%	0 18%	-3 20%	-6 20%	-7 22%



*48 m/sec values are determined from extrapolation of AAFE RADSCAT σ^0_{VV} curves beyond the 3 m/sec to 24 m/sec data range (Reference 4). Wind speeds listed are approximate.

Table II σ^0 Errors

Orbit	Cell No.	θ_i (Nominal)	$\sigma_A, \%$	$K_P, \%$		σ^0 Std. Dev., %	
				4 m/sec	24 m/sec	4 m/sec	24 m/sec
Descending	2	25	7	37	5	41	15
	3	30	6	28	3	32	14
	6	40	2	20	2	25	13
	10	50	2	59	5	61	14
	12	55	4	127	9	129	16
Ascending	1	25	8	30	4	32	16
	2	30	7	23	2	25	15
	4	40	4	14	2	15	13
	7	50	3	29	3	30	13
	8	55	5	72	5	73	15

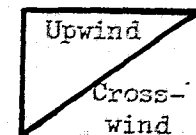
$$\sigma_B = \pm 0.5 \text{ dB (12\%)}$$

$$\sigma_S = \pm 0.1 \text{ dB (2\%)}$$

Table III. Wind Speed Error*

Incidence Angle Wind Speed		Wind Speed Error, m/sec				
		25°	30°	40°	50°	55°
4 m/sec	DESC.	.83	.53	.42	1.08	2.1
		.90	.60	.45	1.15	2.4
	ASC.	.6	.45	.27	.40	1.25
		.8	.46	.28	.53	1.40
24 m/sec	DESC.	1.7	1.6	1.28	1.47	1.8
		2.9	1.6	1.44	1.62	2.3
	ASC.	1.9	1.5	1.28	1.32	1.65
		3.1	1.7	1.44	1.45	2.15

*Wind speed error are bounds for all wind direction



to the low noise preamplifier, band pass filter, and first conversion mixer (figure 3). A local oscillator signal is added to the return signal in the mixer to produce a coherent IF signal which is then fed to the scatterometer processor. The scatterometer processor contains an IF amplifier, a second IF conversion mixer, and 15 processing channels. Each processing channel consists of a range gate, band pass Doppler filter, square-law detector, and gated signal integrator. Fifteen Doppler filters and range gates are used to electronically subdivide the fan beam into separate resolution cells and to exclude interfering signals from the side lobes. The timing and control for the processor are provided by a digital controller (not shown).

The function of the digital controller is to accept spacecraft commands and power, to generate the precise timing and control logic needed by the scatterometer to form RF pulses, and to operate the processor. In addition, it accepts the output scatterometer data and instrument housekeeping parameters and formats them so they are compatible with the spacecraft data system.

The scatterometer design incorporates four dual-polarized antennas which produces a cross-like pattern of illumination on the earth's surface (figure 1). The peak of the antenna beam is centered at 47° incidence angle to favor the outer swath section where the received signals are weaker due to increased range and lower radar scattering coefficient, σ° . Three Doppler cells provide measurements at earth incidence angles of 0° , 4° , and 8° to form the 140 km measurement swath centered about the satellite sub-track. Twelve additional Doppler cells will provide σ° values from about 25° to 65° earth incidence on each side of the sub-track. The effect of earth rotation does cause incidence angles to change typically 4° during each orbit for the outer cells, but the primary swath width is affected to a somewhat lesser degree.

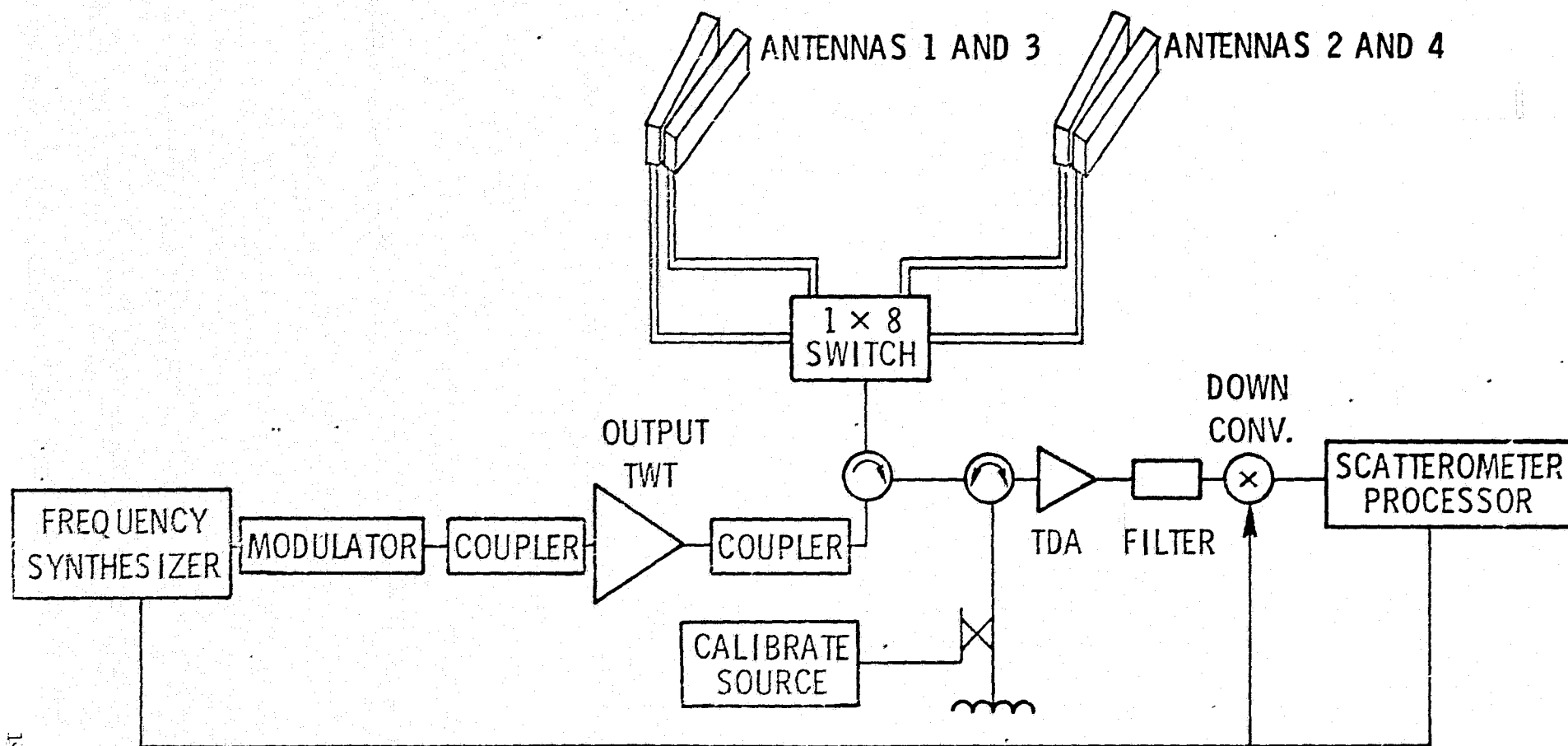


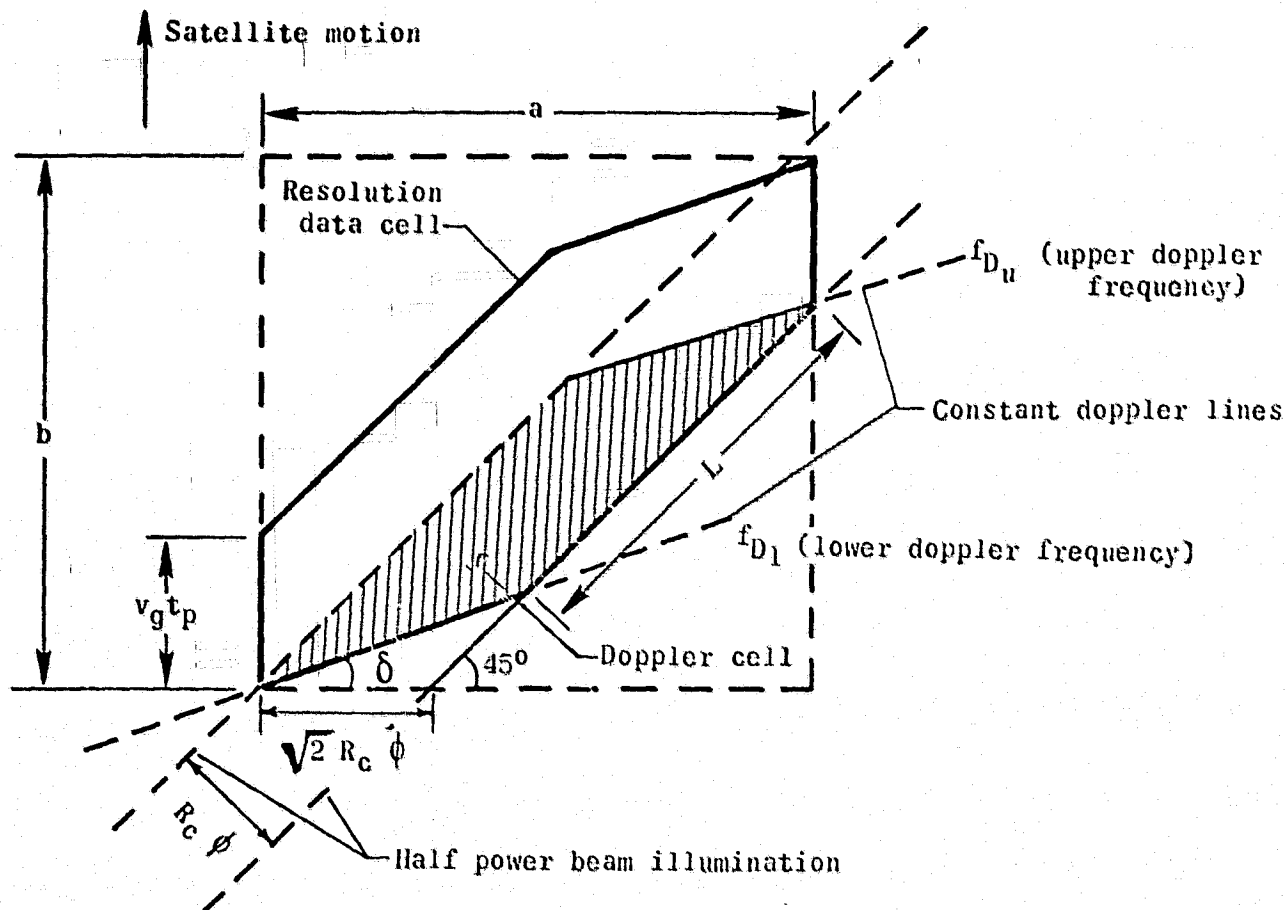
Figure 3. - SCATTEROMETER BLOCK DIAGRAM.

The doppler cells along the fan beam are adjacent so that the cross track grid spacing (center-to-center) can be kept to 50 km and the along-track grid spacing is set at 50 km by the scatterometer digital controller. This design essentially guarantees satisfaction of the 100 km grid spacing requirement. In modes 5 thru 8, the doppler cells give near contiguous coverage for either side of the sub-track to improve coverage in areas where strong wind gradients are expected.

The resolution cell size is larger than the doppler cell size due to the smearing of the cell caused by satellite motion during the measurement period (t_p). The doppler cell size is determined by the antenna beamwidth ($1/2^\circ$) and doppler bandwidth of the filters (figure 4).

Resolution cell size is also controlled by the orientation of the doppler lines within the beam illumination which varies along the beam (figure 1). For the inner cells (low incidence angles) the doppler line is oriented approximately 45° to the central beam axis. For the outer cells (high incidence angles), the orientation is about 13° with respect to the beam central axis. The doppler bandwidths are designed so that the 50 km x 50 km resolution cell size requirement is satisfied over the primary measurement zone ($\sim 25^\circ$ to $\sim 55^\circ$). At angles beyond 55° , doppler bandwidths are held constant so the resolution cell size does increase slightly beyond the 50 km limit. Figure 4(b) gives the nominal range of variation of resolution cell sizes and incidence angles.

The 14.6 GHz signal is switched sequentially through four antenna-polarization combinations taking 1.89 seconds each for a total 7.56 seconds to complete one switching sequence. A switching local oscillator



Satellite Ground Speed = V_g

Data measurement period = t_p

Doppler Bandwidth = $f_{D_u} - f_{D_l}$

Equivalent resolution = $r = \frac{a + b}{2} \leq 50 \text{ km} (25^\circ \text{ to } 50^\circ \text{ incidence angle})$

$$L = \sqrt{2} r - \frac{v_g t_p}{\sqrt{2}} - R_c \phi - \frac{\sqrt{2} R_c \phi \sin \delta}{\sin (135 + \delta)}$$

(a) Geometry of one resolution cell at slant range, R_c .

Figure 4.- SASS resolution cells.

<u>Beam 1 (forward)</u>						<u>Beam 2 (aft)</u>			
Case	Cell #	θ Deg	Area KM ²	Width KM	Length KM	θ Deg	Area KM ²	Width KM	Length KM
Lat. = 0, ascending* (most dynamic case)	1	24.8	1068	16.6	64.3	21.6	872	16.5	53.0
	4	39.6	1204	17.8	67.8	34.0	859	17.2	49.9
	7	51.7	1353	19.4	69.7	43.5	785	18.2	43.1
	12	67.5	2143	23.5	91.3	54.3	722	19.9	36.3
Lat. = 72° (most uniform case)	1	23.2	1008	16.8	60.2	23.2	1008	16.8	60.2
	4	36.8	1056	17.7	59.5	36.8	1056	17.7	59.5
	7	47.5	1054	19.0	55.3	47.5	1054	19.0	55.3
	12	60.3	1180	21.6	54.5	60.3	1180	21.6	54.5

*Note: On a descending track, the cell characteristics of beam 1 and beam 2 reverse.

(b) Resolution cell size and incidence angle as a function of Earth latitude, beam number, and doppler cell number.

Figure 4.- Concluded.

is used to allow both positive and negative returning frequencies from the forward and aft footprints to be received by the same bank of 15 Doppler filters. The ten operating modes for the instrument are listed in table IV.

The antenna numbering convention is defined in figure 1. Modes 1 and 2 are single polarization measurements over the full swath, modes 3 and 4 are dual polarization measurements over one-half swath, and modes 5 through 8 are single polarization measurements over one-half swath which allows doubled integration time (thru ground computer processing) for improved accuracy without significantly increasing the resolution cell size. The fundamental cycle is through the antenna positions such that for example in modes 3 and 4, both vertical and horizontal polarization measurements are made before switching antenna positions. A summary of instrument characteristics is given in figure 1, and details concerning the swath width for each mode is described in a supplement to this report.

7.0 EXPERIMENT DESCRIPTION

7.1 General (See Ref. 5 and 6).

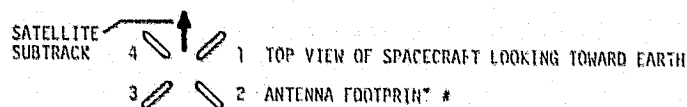
The SASS Experiment is a developmental program aimed at determining the usefulness of high resolution scatterometers in space for geophysical application with emphasis on the acquisition of oceanographic data. The more specific purpose of the scatterometer is to obtain scattering coefficient measurements over the sea and from these deduce the magnitude and direction of the synoptic scale 19.5 m and 10 m neutral stability vector wind and the sea surface wind frictional velocity. The availability of wind information on the required 100 x 100 km grid sample scale will provide oceanographers

TABLE IV

SASS OPERATING MODES

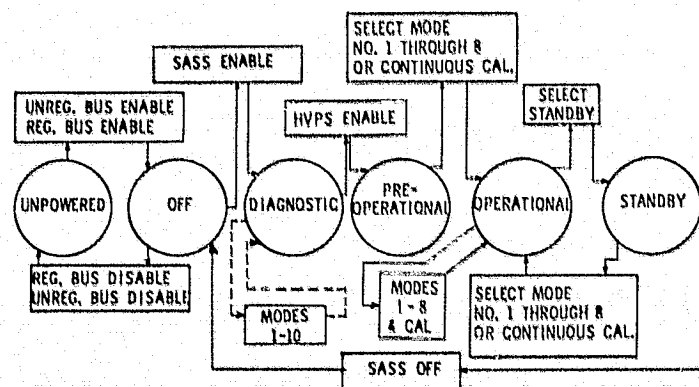
MODE	ANTENNA SEQUENCE ¹	SWATH	PURPOSE
1	4 _V , 1 _V , 3 _V , 2 _V	BOTH SIDES OF SPACECRAFT	PRIMARY MODE VERTICLE POLARIZATION
2	4 _H , 1 _H , 3 _H , 2 _H	BOTH SIDES OF SPACECRAFT	PRIMARY MODE HORIZONTAL POLARIZATION
3	4 _V , 4 _H , 3 _V , 3 _H	LEFT SIDE ONLY	COMPARISON OF α^* AT NEARLY THE SAME GEOGRAPHIC SITES FOR BOTH POLARIZATIONS
4	1 _V , 1 _H , 2 _V , 2 _H	RIGHT SIDE ONLY	COMPARISON OF α^* AT NEARLY THE SAME GEOGRAPHIC SITES FOR BOTH POLARIZATIONS
5	4 _V , 4 _V , 3 _V , 3 _V	LEFT SIDE ONLY	IMPROVED α^* ACCURACY (40%) OR WIND GRADIENT INDICATORS
6	1 _V , 1 _V , 2 _V , 2 _V	RIGHT SIDE ONLY	IMPROVED α^* ACCURACY (40%) OR WIND GRADIENT INDICATORS
7	4 _H , 4 _H , 3 _H , 3 _H	LEFT SIDE ONLY	IMPROVED α^* ACCURACY (40%) OR WIND GRADIENT INDICATORS
8	1 _H , 1 _H , 2 _H , 2 _H	RIGHT SIDE ONLY	IMPROVED α^* ACCURACY (40%) OR WIND GRADIENT INDICATORS
9 ²	NOT APPLICABLE	NOT APPLICABLE	CONTINUOUS CALIBRATE (TWT ON BUT INHIBITED FROM TRANSMISSION)
10 ²	NOT APPLICABLE	NOT APPLICABLE	STANDBY (TWT HIGH VOLTAGE IS OFF BUT HEATER IS ON)

¹ NUMBER INDICATE FOOTPRINT AND SUBSCRIPT INDICATE POLARIZATION (V FOR VERTICAL AND H FOR HORIZONTAL) SEE ANTENNA FOOTPRINT NUMBERING CONVENTION BELOW.



² SINCE THE TWT HEATER IS ON IN THIS MODE, THE TWT LIFE WILL BE REDUCED AS THOUGH IT WERE TRANSMITTING AS IN MODES 1 THROUGH 8.

COMMAND SEQUENCE DIAGRAM



- NOTES:
1. IN DIAGNOSTIC STATE LOGIC IS SWITCHING IN MODE 5 EXCEPT AS INDICATED BY THE DASHED LINE.
 2. AFTER SASS ENABLE BUT BEFORE HVPS ENABLE ANY ONE OF MODES 1-8 MAY BE SELECTED FOR A RADIOMETRIC TYPE MEASUREMENT
 3. THE PREOPERATIONAL STATE INCLUDES AN AUTOMATIC 3 MINUTE TIME OUT
 4. THE SASS MUST BE IN STANDBY PRIOR TO SASS OFF
 5. IN STANDBY, LOGIC IS SWITCHING IN MODE 5 AND RADIOMETRIC TYPE DATA ARE TAKEN
 6. MODE MUST BE SELECTED AFTER 3 MINUTE TIMEOUT TO PREVENT INPUT CURRENT TRIP, OTHERWISE MODE CMD MUST BE REPEATED TO CLEAR TRIP. (MODE CMD MUST BE REPEATED IN ANY CASE TO CLEAR TLM STATUS BIT FOR INPUT CURRENT TRIP.)

and meteorologists with significantly improved input parameters for models from which wave and weather forecasts are developed. Deduction of wind information will utilize correlations of the NRCS with neutral stability surface wind or wind frictional velocity over the ocean, obtained in a coordinated NASA/NOAA sea-surface truth program involving measurements from aircraft, oceanographic research vessels, and bouys.

The frequency of the scatterometer was chosen in the Ku-band range where the radar backscatter, for incidence angles tens of degrees off nadir, is proportional to the vector wavenumber spectrum of waves a few centimeters in length. Since these capillary waves are generated by the wind near the sea surface, the radar measurement of their amplitude can in turn be used to infer this local wind. To be consistent with previous investigations, the surface wind shall be referred to 10.0 m and 19.5 m altitude using a logarithmic profile for a zero air-sea temperature difference (neutral stability conditions). An agreed upon relationship between $\vec{u}_*$ and Z_0 , the roughness length, will be used to generate the magnitude of u_* (the magnitude of $\vec{u}_*$ can vary by as much as 10 to 20% depending upon the relationship shown). This procedure produces a windspeed that would have been measured at these altitudes in a neutrally stratified atmosphere with an adiabatic lapse rate. Unless otherwise specified, any reference to wind vectors in the remainder of this plan will be for these neutral stability wind vectors.

To the first order, the scattering coefficient for a given incidence angle, look azimuth, and polarization depends only upon the wind speed and direction. Two measurements of the scattering coefficient at a given earth cell are made at different azimuths (one from the forward antenna and one from the rear). These measurements provide the necessary input data for the

algorithms described in section 7.2.3 to infer the wind vector and a number of aliases (typically three or less). The presence of noise (instrument and geophysical) in the scatterometer measurements causes an uncertainty in the inferred wind vector, which can be defined in terms of a closed curve with an assigned a priori probability of enclosing the true wind. Multiple solutions will be eliminated in post flight data processing by the application of meteorological principles. Also, the possibility of using the data itself to eliminate some aliases is under investigation.

SASS data will be used to conduct experiments for the Experiment Team, on-going oceanographic programs, and marine industrial programs. Tasks, which have been identified are listed in Table V. The efforts involving the Experiment Team include:

- (1) Evaluation of sensor performance. After initiation of Engineering Assessment (section 7.2.1), SDR's will be available for use in sensor validation. Details of these validation activities are given in section 7.2.2 and are summarized below.

Data sources used for sensor validation are listed in figure 5 and would be used to accomplish the various validation methods. The schedule for these activities is given in figure 6 showing an intensive sensor validation period the first 4 months after launch with periodic review of sensor performance monthly. Thereafter, targets-of-opportunity activities will be scheduled as required.

- (2) Evaluation of the sensor's capability to infer valid winds from NRCS and supplemental data. This task includes:

Table V. Tasks Supported by SASS Data

SAGE EXPERIMENT TEAM

- SENSOR PERFORMANCE
- GEOPHYSICAL ALGORITHM EVALUATION AND IMPROVEMENT IN WIND MEASUREMENTS
- IN SITU AND BOUY DATA GATHERING
- HURRICANE CASE STUDIES
- EXTRA TROPICAL STORMS
- OCEAN UPWELLING
- SEA ICE MAPPING
- ARTIC WINDS AND FLOE ICE
- CIRCULATION IN SUBTROPIC REGIONS
- EKMAN TRANSPORT PHENOMENA IN B. L.
- METEOROLOGICAL FORECASTING AT FTWC, GISS, and NMC
- OVERLAND GEOPHYSICAL APPLICATION
- PLANETARY BOUNDARY LAYER

ON-GOING OCEANOGRAPHIC EXPERIMENTS

FCGE
NORPAX
JASIN
POLYMODE
ISCS
MCNEX

GRANTHAM (NASA-LaRC)
PIERSON (CUNY); MOORE (U OF K); WOICESHYN (JPL)
JONES (NASA-LaRC), WENTZ (WENTZ ASSOC.)
BAER & DELECHIBUS (NOAA)
BLACK (NOAA), WOICESHYN (JPL)
PIERSON (CUNY), WOICESHYN (JPL)
APEL (NOAA) & SCRIPS (SUGGESTED)
JONES (NASA-LaRC); MOORE (U OF K)
MOORE (U OF K)
PIERSON (CUNY), WOICESHYN (JPL)
JONES (NASA-LaRC)
CANE (GISS), HALBERSTRAM (JPL), McPHERSON (NRC)
and GORRICH (NEPRF)
KRISHEN (NASA-JSC)
WOICESHYN (JPL)

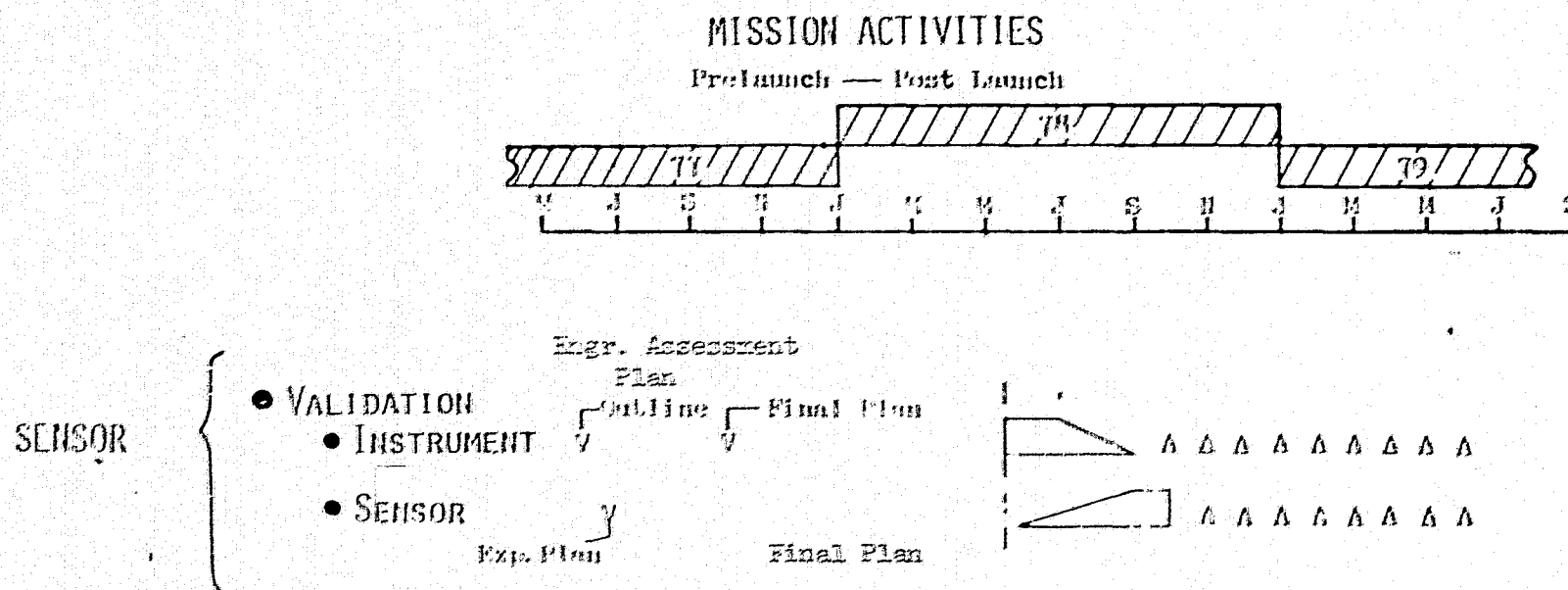
ASVT PROGRAM (SEASAT-A INDUSTRIAL EXPERIMENTS)

OCEAN ROUTING & ENVIRONMENTAL PREDICTION - OCEAN ROUTES INC.
ICEBREAKING VESSELS & OPTIMUM ROUTING - SUN SHIP BUILDING
OFF-SHORE OIL & GAS - CONOCO
CANADIAN PARTICIPATION - CANADIAN CTR FOR REMOTE SENSING
TROPICAL TUNA FISHERIES - INTER-AMERICAN TROPICAL TUNA COMM.
INTERNATIONAL ICE PATROL EXPERIMENT = INT'L ICE PATROL (USCG)
ALASKAN CRAB FISHERIES - FISHING VESSEL OWNERS ASSOCIATION

PRIMARY DATA SOURCE	METHOD
AIRCRAFT AND SPACECRAFT	ABSOLUTE σ^0 COMPARISON
	TIME VARIANCE OF σ^0
	• SHORT TERM • LONG TERM
SPACECRAFT AND SURFACE TRUTH • Ships • Bouys • Aircraft	DIFFERENTIAL σ^0 COMPARISON
	• VV/HH • FORE AFT
	SASS SELF-DETERMINATION STABILITY
	COMPARISONS OF ALT/SASS σ^0 VALUES
	AZIMUTH ROTATION EXPERIMENTS
	• TROPICAL STORM HIGH RESOLUTION • ANTENNA PATTERN EVALUATION • σ^0 VS INCIDENCE ANGLE
	RADIOMETRIC ANTENNA EVALUATION

Figure 5. Data sources used for sensor validation.

Figure 6.1 Mission activities for sensor validation.



(a) Development and an assessment of the validity and limitations of algorithms to make atmospheric attenuation corrections of the NRCS data when the SASS measurement cell is filled by clouds or rain cells. These algorithms will utilize VIRR and SMMR data to detect and quantify the required correction.

(b) Comparison with SUS underflight data, insitu data, and pre and post-flight conventional forecasts to evaluate and upgrade the wind algorithms. Algorithms are under development at CUNY (W. J. Pierson), U. of Kansas (R.K. Moore) and Wentz (F. J. Wentz), which will combine fore- and aft-SASS NRCS measurements and infer the vector winds and friction velocity. The algorithms need to be validated to determine if they are producing realistic wind speeds and directions, and compared to surface truth data from planned test sites. The removal of multiple solutions for direction has not presently been resolved, and additional inputs such as from conventional meteorological analyses will be required for this purpose. The generation of the wind algorithms is considered to be in the evolutionary state and the effects of parameters now considered to be second order (such as the directional wave spectrum and atmospheric stability) can be added as they are understood. In addition, the sensitivity of the sensor under a wide range of conditions needs to be studied; for example, for neutral stability, a threshold below which capillary waves are not generated occurs at $U_{19.5}$ of about 3.5 m/sec - this effect and the possible upper limit needs to be explored and quantified.

(c) Systematic deduction of friction and wind velocities from the SASS NRCS data to improve both the data base and the algorithm. The algorithms for conversion of NRCS to winds will be based initially on the

limited data obtained during aircraft- and Skylab-scatterometer missions. After examination and validation (as discussed in (2b)) the SASS data coupled with insitu and other independent observations are expected to provide an improved data base with a much wider scope which will be added to (and eventually replace) the initial data base. The use of this expanded data base will allow the generation of a refined error analysis of the radar-inferred wind vector.

(3) The gathering of in situ and bouy data. The S193 program for Skylab encountered a great deal of difficulty in obtaining accurate winds from conventional meteorology data against which to compare the winds computed from backscatter. Even for ships with anemometers, the short averaging time introduced substantial error, which was compounded by the need to interpolate over large distances and between synoptic measurement times. For SeaSat A, the expanding global international array of meteorological data buoys augmented by weather skips (ocean station vessels) will be utilized to obtain improved hourly wind values. Moreover, SASS measurement cells are located close together (see figure 7) such that within a swath passing over a surface truth site, there is better than a 50% probability that the site will be within the cell if the SASS is taking data on both sides of the sub-track and about 75% probability if the SASS is operated in the one side only increased resolution mode. Thus, two major sources of scatter (or error) encountered by Skylab will be minimized. Plots of radar wind versus the meteorological wind will therefore show reduced scatter, and these results can be used to look for error effects which depend on the algorithm. The gathering of SeaSat-A surface truth data will be coordinated by NOAA (Ernst and Wilkerson - NESS, ref. 5 and 6). It is planned that FNWC

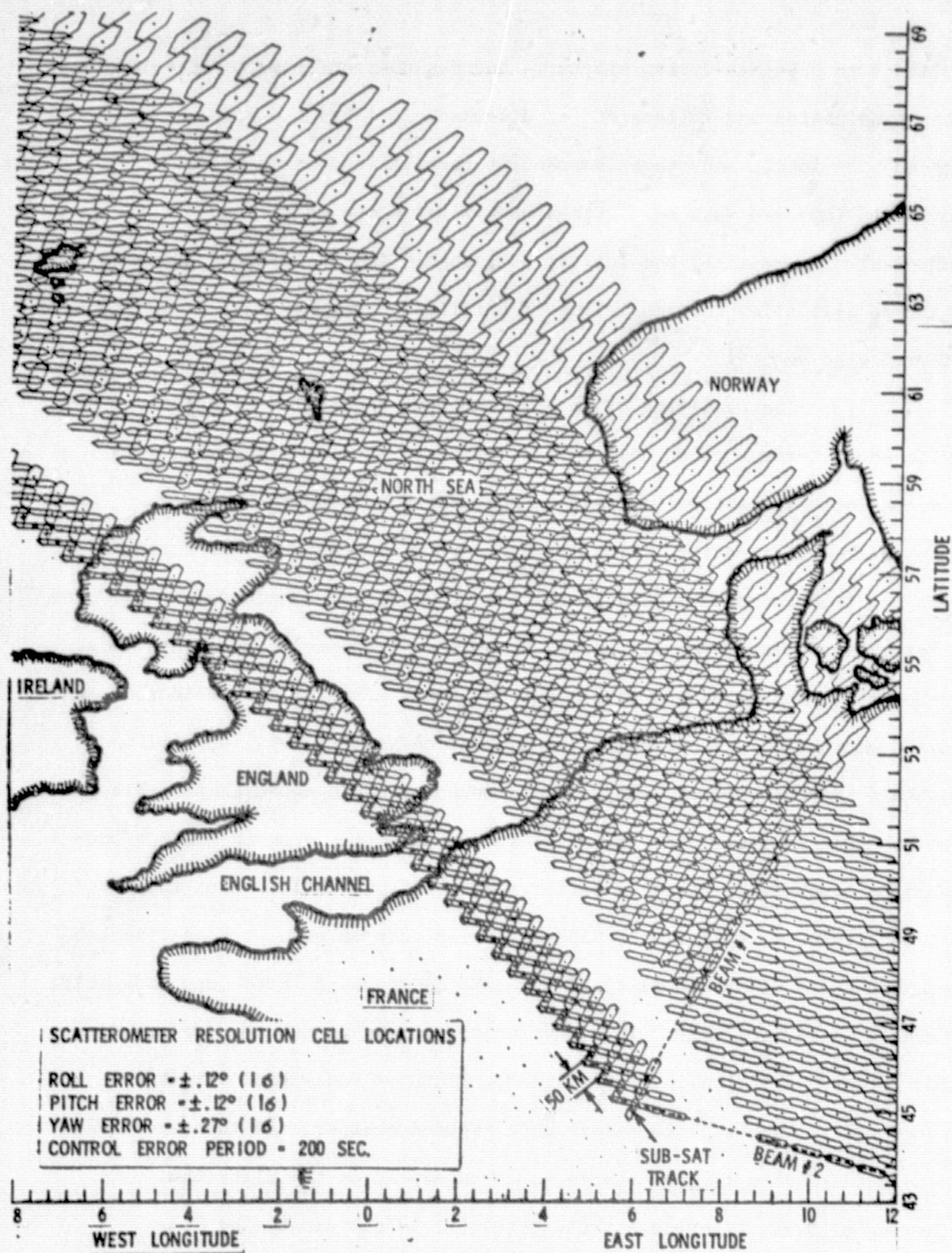


Figure 7.- SASS resolution cell locations.

will provide most of these data to the project on a regular basis.

(4) Operational use of the SASS for weather forecasting. A substantial effort is underway to prepare the computer software needed to utilize the SeaSat-A data on a real time operational basis at FNWC so as to obtain improved meteorological forecasts in the one to four day time frame. In addition, non-real time weather forecasting experiments will also be conducted with the Goddard Space Flight Center (GSFC) to assess the utility of SASS measurements. Halberstram of JPL, Goroch of NRPRF and Cane of GSFC are the scientists responsible for these efforts. Also, NOAA NWS/NMC will test the impact of SASS-deduced winds on operational atmospheric and wave forecast models. Flittner is the responsible person.

(5) Special Ocean case studies. A number of ocean case studies have been identified by various team members. A partial listing of the studies being planned follows, and an abstract of each is given in an attached appendix.

- (a) Hurricanes - NOAA (P. Black) in consultation with U. of K. (Moore).
- (b) Extratropical storms - CUNY (Pierson)
- (c) Winds around islands and continents - CUNY (Pierson)
- (d) Circulation in the subtropic regions - CUNY (Pierson)
- (e) Sea breeze - CUNY (Pierson)
- (f) Arctic winds and ice floes - U. of K. (Moore)
- (g) Ocean upwelling - NOAA (Apel) & Scrips
- (h) Mapping of sea ice - LaRC (Jones) and U of K (Moore)
- (i) Ekman transport in the boundary layer - LaRC (Jones)
- (j) Gulfstream currents - LaRC (Jones)
- (k) SASS-Geosynchronous satellite - Wind analysis of tropical storms - NASA GSFC & JPL (Woiceshyn).

In addition, there are many important details of the winds over the ocean and of the distribution of sea ice that can be studied in terms of the SASS data. These details can be studied by means of the classical case study method in which appropriate subsets of the SeaSat data stream are analyzed on a non-real time basis to learn about various circulation features.

(6) Special case studies for overland geophysical use. For this case simultaneous SMMR and SASS data will be collected overland and analyzed to identify potential geophysical applications. Whenever possible, SASS measurements will be coordinated with ongoing research programs. This task will be the responsibility of Krishen at JSC and Moore of U. of K.

7.2 Functional Implementation (see Ref. 3, 7, 8, 9)

The purpose of this paragraph is to provide a general description of the SASS Experiment Team activities during the conduct of the SeaSat-A mission. The activities fall into three major areas, namely; engineering assessment (ref. 7), sensor validation, and geophysical evaluations (ref. 8).

7.2.1 Engineering Assessment

This activity is the sole responsibility of the Sensor Implementation Manager and is limited to an evaluation of SASS electronic elements. A summary of this activity is given below. For details see reference 7. The purpose of the instrument engineering assessment is the determination of the operating condition of SASS as determined from the SDR.

The engineering assessment will include:

(1) A functional verification that the SASS instrument responds to commands and operates in the required experimental and calibration modes.

(2) An engineering verification that the instrument outputs are within design limits and are stable.

(3) An evaluation/determination of the instrument performance in certain critical areas.

Engineering assessment reports will be written by the Sensor Implementation Manager for both the initial and extended phases.

7.2.2 Sensor Validation

The SASS Sensor Implementation Manager in cooperation with the Experiment Team will conduct such pre- and post-launch testing and analysis as is required to assess the performance of the sensor relative to its design characteristics. Proposals to accomplish the task and their resultant requirements for mission operations, surface truth data, and data processing are provided herein. It is anticipated that this sensor validation will be completed within 3 months following availability of the SDR with periodic revalidation thereafter as required.

Described in this section are the specific ways available to demonstrate sensor performance during the 1 year post launch mission. Some of the validation activities described below require substantial budgetary support and prelaunch preparation.

7.2.2.1 Comparison of Satellite and Aircraft σ^0 Measurements

There are certain minimum requirements that must be met to certify the SeaSat Scatterometer after it is placed in orbit. The sensor validation period will begin immediately after launch with intensive activity for 3 to 4 months; after that, periodic checks are needed to verify long term stability. During the validation period (1 yr.), underflights are required with an aircraft qualified scatterometer, SeaSat Underflight Scatterometer (SUS), so that direct comparisons can be made between the

aircraft and satellite σ^0 measurements. Specifically the flights can be categorized as shown on Table VI. This table lists 5 categories of flights, 3 for sensor validation and 2 for geophysical validation, which were requested in the official NASA aircraft support document. A summary of the characteristics of the SUS instrument is given in figure 8. The details of the footprint of the SUS are compared to those typical of the satellite for the sensor validation absolute calibration tests and for the geophysical verification 360° azimuth data tests (see section 7.2.3.4) in figures 9(a), (b), (c), and (d). The data obtained from underflights will be utilized to validate a particular feature of the sensor as described in the following.

(1) Absolute σ^0 Accuracy Comparison

From a direct σ^0 comparison between aircraft and satellite data (for the same resolution cell, incidence and antenna look angles, polarization, etc.), the level and time stability of biases between the two σ^0 values can be established. Using the aircraft SUS instrument which will be accurate to $\pm .5$ dB in σ^0 , fixed biases could be removed (if present) so that the satellite σ^0 measurements can be related directly to wind vector (through the geophysical algorithm). If underflights were not provided, then the SASS would have to use extensive surface truth collected over a period of several months as a means of calibration. This has the obvious undesirable effect of delaying the availability of accurate SASS data, and it removes the option of definitive sensor diagnostics. Therefore, it would be extremely difficult to separate potential sensor uncertainties and algorithm related wind vector inaccuracies.

Table VI. Aircraft Underflights Planned.

Flight Type	Objective	Description	No. of Flts.	Schedule (Estimates)					
				Jan. 1978	Apr. 1978	July 1978	Oct. 1978	Jan. 1979	Apr. 1979
Prelaunch	Certification & Evaluation of SUS	Patterns Similar to A and D Below	1	▽					
Sensor Validation	Absolute σ^0 Transfer the +1/2 dB cal. of SUS to SASS	Aircraft Flt. Across Swath to Measure σ^0 Corresponding to Each Resolution Cell (Figure 9)	3			▽		▽	▽
Sensor Validation	Long Term Stability	Same as Above	6			▽	▽		▽
Sensor Validation	Short Term Stability	Aircraft Flt. Parallel to Sub-track to Measure Short Term Variations of Cell σ^0 & Compare with Swath	2			▽	▽		
Geophysical Validation	Wind Field Improvement and Alias Resolution	360° Azimuth Scans Will Be Made for Each SASS Resolution Cell (Both Pols) Across the Satellite Swath	2				▽	▽	
Geophysical Validation	Insitu Data For Targets of Opportunity	Fly Low Altitude w. Speed and Laser Insitu Sensing Lines in H. or Othric Targets of (No Scatterometer Required)	3		▽	▽		▽	▽

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SUS Instrument Characteristics

Frequency - 14.6 Ghz

Power - 0.1 W or 20 W

Antenna

- o Beamwidth - 3.5°
- o Polarization - VV, HH
- o Footprint range @ 7.6 km
 - 0.46 km x 0.46 km
 - 1.86 km x 0.93 km

Azimuth range - 0° to 360°

Incidence angle range - 0° to 60°

NRCS range - -20 to -35 dB

NRCS accuracy - ± 0.5 dB

NRCS resolution - ± 0.25 dB

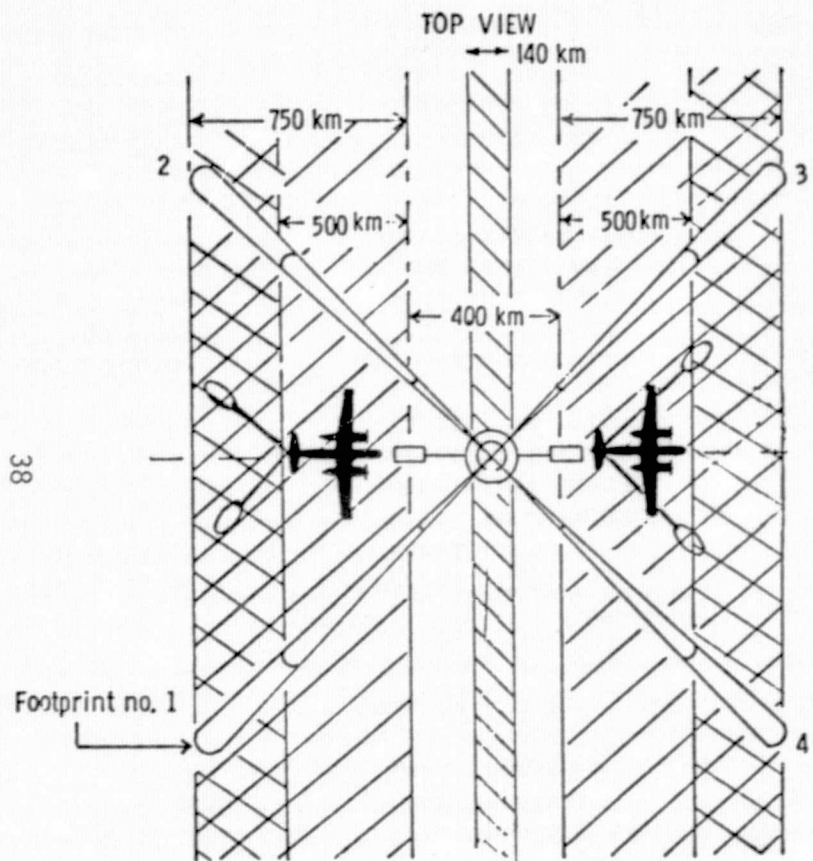
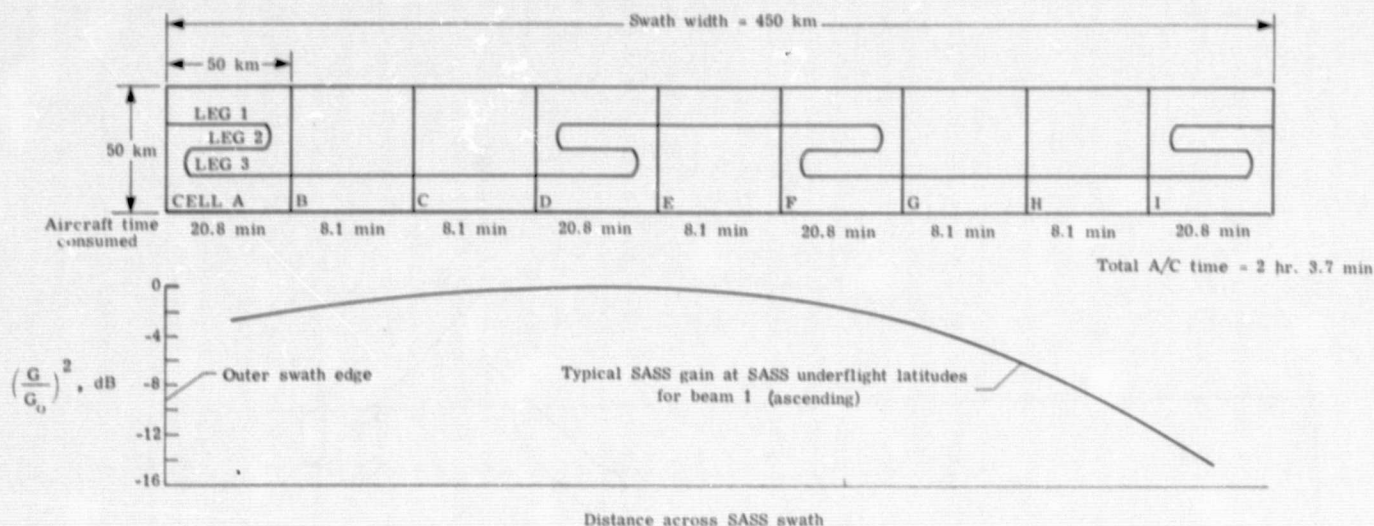


Figure 8. - Aircraft underflights for SASS calibration.



(a) Plan view of SUS underflight compared to SASS antenna gain pattern.

SUS cell			Best comparison with SASS cells											
			Beam 1						Beam 2					
Cell no.	Dist. to subtrack, km	θ_1 , deg	Cell no.	Dist. to subtrack, km	θ_1 , deg	ℓ , km	w, km	A_s , km ²	Cell no.	Dist. to subtrack, km	θ_1 , deg	ℓ , km	w, km	A_s , km ²
I	225-275	24.3	1	223.3	24.3	65.9	16.2	1065	2	245.3	26.5	56.4	16.3	918.8
H	275-325	29.4	2	277.5	29.4	66.8	16.5	1110	3	291.0	30.7	55.4	16.6	916.9
G	325-375	34.2	3	332.6	34.2	67.5	16.8	1136	4	335.6	34.6	55.6	16.9	937.8
F	375-425	38.7	4	388.2	38.7	70.1	17.2	1208	5	379.7	38.1	51.9	17.2	892.1
E	425-475	42.9	5	445.3	42.9	68.0	17.7	1202	7	464.8	44.3	46.0	17.9	821.6
D	475-525	46.7	6	503.3	46.7	67.3	18.2	1226	8	505.7	47.0	44.3	18.2	807.4
C	525-575	50.3	7	563.0	50.3	65.7	18.8	1233	9	545.3	49.4	41.4	18.6	769.5
B	575-625	53.6	8	624.3	53.6	66.7	19.3	1290	11	621.4	53.7	39.2	19.3	758.6
A	625-675	56.8	9	687.2	56.8	65.8	20.0	1316	12	657.5	55.5	39.2	19.7	772.2

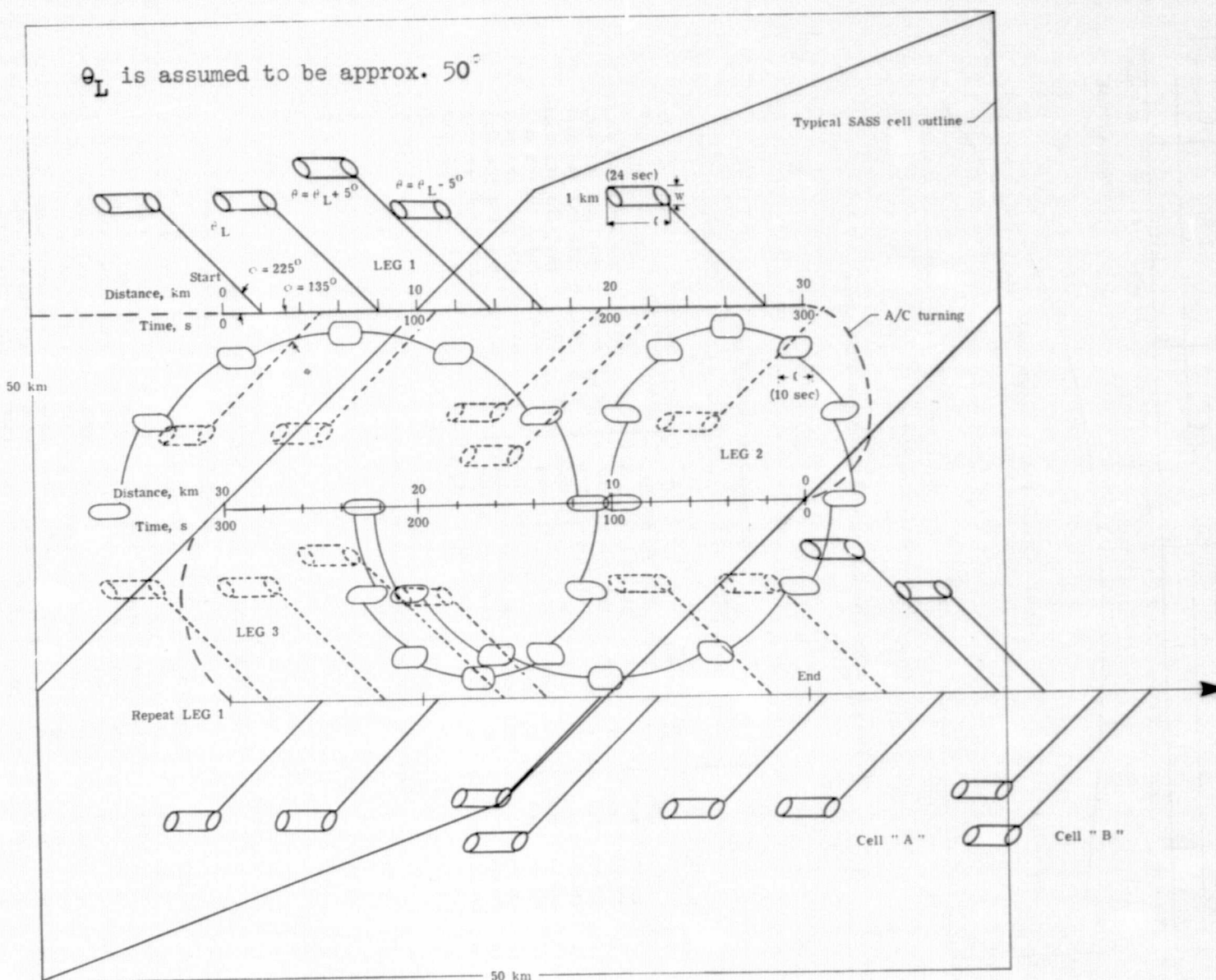
(b) Typical SASS cell parameters in cells sampled by SUS.

SUS cell size, Sensor validation legs					SUS cell size, Geophysical validation legs					
					Min. size, $\phi = 0^\circ$			Max. size, $\phi = 90^\circ$		
Cell No.	θ_i	ℓ_i km	w_i km	A_i km ²	ℓ_i km	w_i km	A_i km ²	ℓ_i km	w_i km	A_i km ²
I	24.3	2.93	0.395	1.233	1.56	0.509	0.794	1.51	0.559	0.844
H	29.4	2.97	.432	1.363	1.61	.533	.859	1.53	.612	.938
G	34.2	3.02	.480	1.533	1.68	.561	.942	1.56	.679	1.060
F	38.7	3.08	.539	1.947	1.76	.595	1.048	1.60	.762	1.215
E	42.9	3.15	.612	2.017	1.86	.634	1.182	1.63	.865	1.413
D	46.7	3.23	.698	2.343	1.99	.677	1.345	1.68	.987	1.655
C	50.3	3.33	.805	2.759	2.14	.727	1.554	1.73	1.138	1.965
B	53.6	3.45	.932	3.267	2.32	.782	1.813	1.78	1.318	2.349
A	56.8	3.60	1.095	3.941	2.55	.848	2.161	1.85	1.548	2.861

(c) Typical cell parameters for beam 1 (ascending) at SASS underflight latitudes.

Figure 9.- SUS aircraft underflight characteristics and plans compared to SASS swath characteristics. (Assumptions: underflight perpendicular to SASS swath, aircraft ground speed = 100 m/s, typical SASS beam 1 characteristics, ascending track.)

04



(d) SUS underflight characteristics for cell "A" compared to SASS cell.

Figure 9.- Concluded.

(2) Differential Measurements and Time Variance of σ^0

Additional benefits in establishing validity in the satellite instrument are derived by comparing differential measurements of both instruments such as the increment between polarizations for adjacent doppler cell (modes 3 and 4). Also, in the differential σ^0 comparison, long term drifts in either the aircraft or satellite instrument are not important and a more reliable relative antenna gain can be established for both polarizations. Furthermore, differential polarization measurements, are more accurate and may provide important geophysical information.

Another test using the differential method is to compare the satellite differential σ^0 values (for example between footprints 1 & 2 on figure 1) to aircraft differential values for the same azimuth angles and resolution cell. This again removes long term errors that might otherwise confuse the short term test results. Relative antenna gain between the fore and aft antenna is a definite factor that can be evaluated since the aircraft instrument will be using the same antenna for both azimuth measurements and the satellite instrument will not.

Long term instrument stability characteristics will be determined from periodic (monthly) comparison of σ^0 measurements from the aircraft and satellite scatterometers. Long term stability checks are also possible thru examination of the σ^0 satellite data at 8° earth incidence angle (aircraft data is not required) as will be discussed in section 7.2.2.2.

Another differential test that would isolate antenna pattern effects would be to take advantage of earth rotation effects which cause incidence angle to vary up to 4° , for any given Doppler filter. Since the antenna pattern is a function of incidence angle, one Doppler filter can be evaluated for two or more antenna gain values (as much as 4 dB apart)

with all other factors the same. Surface conditions would have to be the same for both measurements also as determined from surface truth data. The slope of the antenna pattern could be determined for satellite orbit configuration but a ground based receiver experiment may be more accurate if properly implemented (see 7.2.2.4).

(3) σ^0 vs. Incidence Angle Comparison

A beneficial sensor quality check of short and long term stability can be realized by comparing satellite derived curves of σ^0 vs. incidence angle θ_i with (1) aircraft σ^0 data and (2) theoretical scattering cross section values. This type of comparison evaluates both relative and absolute accuracies of the 15 Doppler cells, including a check of relative antenna pattern gain values that can be peculiar to each Doppler cell and relative differences between electronic gain levels for each Doppler filter channel. This σ^0 vs. θ_i curve-comparison-method has an advantage over point-by-point comparison since it would show whether error trends are common for all Doppler channels and would suggest thru the composite use of the data the amount of bias error and the sign. When comparing satellite data with theoretically derived values, this method is mutually beneficial, since all aspects of the theoretical model are not yet confirmed. Two satellite orientations are desired: One with the scatterometer antenna azimuth angle oriented at 45° , 135° , 225° , 315° , which is the normal orientation for data taking; the other orientation is with the satellite rotated $\leq 45^\circ$ in azimuth so that antenna azimuth angles are changed to 0° , 90° , 180° , and 270° . In the second orientation, two scatterometer footprints would be aligned with the satellite subtrack during the test and σ^0 data at different incidence angles could be obtained for the same ocean target. This reduces data scatter caused by geophysical variables that would not otherwise be duplicated if separate sites were used and is therefore the preferred orientation for this type of

test. If the satellite azimuth rotation is not possible, then σ^0 data taken at different incidence angles must have more extensive ground truth measurements to avoid excessive data scatter.

7.2.2.2 Time Stability Self Determination Using Near Nadir Data

Aircraft σ^0 measurements (in the 8° to 12° incident angle range) have been shown to be relatively insensitive to ocean surface winds and waves. For this reason wind speed cannot be determined from the scatterometer in that angular region and was not proposed for SeaSat-A. NRCS measurements at 8° can be used, however, as an overall indicator of relative sensor stability independent of the ocean surface winds. It is envisioned that once validity of this technique has been demonstrated, σ^0 at 8° would be monitored as a matter of routine.

It is required that surface truth data at a number of instrumented sites provide information describing surface roughness conditions and that overflights be made with the SASS to develop a library of data needed to demonstrate this insensitivity. The widest possible range of surface roughness conditions are required which suggest a number of test sites. SeaSat Altimeter wave height data is also required in this and in the Azimuth Rotation experiment (7.2.2.1) to supplement the ground truth data.

7.2.2.3 Correlation and Data Use From Other SeaSat Sensors

The quality of the SASS σ^0 data can be further checked and improved using data from other sensors on the SeaSat-A satellite. Comparison can be made, for example, between σ^0 values measured at nadir by the altimeter and scatterometer. Relative biases may be determined and their variance with time which can be used as an indicator of the long term drift

in either instrument. Since σ^0 values at nadir may change as much as 25 dB, depending on the sea state, the σ^0 comparison gives a good check for the two instruments over significant portions of their dynamic ranges. It is expected that this dynamic range test could be made several times during a single orbit.

As mentioned in section 7.2.2.2, the sea state values derived from the altimeter will be extremely useful for providing surface truth data for the scatterometer. Correlation of scatterometer and SMMR data relates primarily to wind vector and is covered in another section.

7.2.2.4 SASS Subsystem Validation

Extensive in-flight housekeeping data are being provided routinely by the scatterometer in addition to planned subsystem level performance validation and diagnostic activities described below.

In one of the case studies described in the Appendix, an array of three land-based receivers is proposed to verify transmitter performance as well as the antenna gain and pattern shape. This technique was used on the Skylab S193 (RADSCAT) experiment (ref. 9) and it offers the only means of evaluating the transmitter and antenna on a subsystem basis. Enhancement of this technique is realized if performed during the Azimuth Rotation described in 7.2.2.1.

For diagnostic purposes, the SeaSat A scatterometer can be operated as a 14.6 GHz radiometer (transmitter inhibited). This radiometric capability is achieved by placing SASS in the "SASS Enable" state and in any mode (Mode 1 thru Mode 8, ref. 3). Receiver losses and noise temperature stability can be monitored throughout the mission, independent of the internal calibration source, by using this radiometric capability with the sea surface as a target.

7.2.2.5 Improved Future Scatterometer Designs

Several sensor features are being used for SeaSat-A that would help better define scatterometer sensitivity to geophysical parameters.

Included are dual polarization, near nadir measurements, and the azimuth rotation concept. Listed below are some specific uses of SASS data.

(1) Establish More Definitive Design Boundaries for
Future Scatterometers

By cataloging and evaluating σ^0 data at all SASS angles of incidence, over ocean sites where surface truth are obtained, it will be possible to better define σ^0 sensitivity to wind vector, air/sea temperature, sea state, etc. SeaSat-A will provide σ^0 data for a wider range of geophysical conditions and angles of incidence than is presently available from either Skylab or aircraft scatterometers. In future applications the optimum scatterometer swath could therefore be used for minimum sensor electronics and antenna requirements.

(2) Evaluation of Scatterometer High Resolution
Measurement Capability

During the early phases of user requirements definition for SeaSat-A, interest was shown in high resolution wind vector measurements. These would be used mainly where strong meteorological gradients exist (storm fronts, hurricanes, etc.). The scatterometer can provide a demonstration of its high resolution wind speed capability (12 x 20 km) in the azimuth rotation mode. (See Experiment I in the appendix for a summary of an experiment to evaluate the use of high resolution winds in hurricanes.)

(3) Improvement of Theoretical Model For Study of
Scatterometer Sensitivity

The present plan for SASS error source identification is thru cataloging of data over a wide variety of surface conditions so that second order geophysical effects may be identified. Another approach will include the use of SASS data in conjunction with present theoretical

modeling techniques to sort out validity of limiting assumptions in the model. Once confidence is established in the model, parametric error analyses and even correction techniques may be developed concerning the higher order geophysical effects.

7.2.3 Geophysical Evaluation

In this section the Experiment Team responsibility and plan of action concerning geophysical evaluation is described. (The ADF/GPCF algorithms and activities will be discussed in Section 9.3.) The responsibility of the Experiment Team is to analyze project-provided sensor and supplementary data to evaluate algorithm performance relative to the geophysical parameters sought. The team will make an objective value assessment of the sensor data to scientific- and user-interest, and will communicate this assessment to their peers in the oceanographic and remote sensing community in the form of coordinated team papers and reports.

It is anticipated that this activity will be a coordinated team effort. The evaluation process will include an intensive initial period, estimated at 6 months duration, followed by an extended period of periodic checks until approximately 18 months post-launch. All mission operations and data processing requirements to accomplish this task are defined in this plan and must be provided by JPL within limits set by available resources and system capabilities.

7.2.3.1 Wind Vector Algorithm-Comparison With Surface Truth

The objective of this task is to demonstrate the ability of the SASS geophysical algorithm to deliver to users valid geophysical data over a range of meteorological and surface conditions. This will be accomplished by establishing a set of baseline σ^0 data, to demonstrate quality of scatterometer wind vector measurements whenever

corresponding high quality surface truth (wind speed and direction, air/sea temperature, sea state, etc.) can be obtained for that same resolution cell.

The set of baseline data will be composed of all data obtained (both satellite and supporting) when the satellite swath area passes over a quality data site identified by the experiment team, (see 7.1(3)) or underflight line. At present, Pierson of CUNY predicts 20 such crossings per day, and the Project indicates these activities will be limited to 3 to 5% of the total SASS data potential. Procedures for merging and comparing insitu with SASS inferred data are still under development, but are shown in the conceptual form in figure 11 (which will be discussed in section 9.3).

The σ^0 data will be processed to produce wind vectors as shown in figure 10 (data processing is discussed in section 9.3). Steps indicated in these processes include atmospheric correction to the scattering coefficient, associating fore and aft scattering measurements from a given earth location, conversion of scattering measurements obtained to wind vector, identification of alias solutions, and finally the output of the wind vector and its associated errors. Several algorithms for conversion to wind vector are planned to be developed; therefore, it is of paramount importance that these wind vector algorithms (including those implemented at FNWC) be a sub-process within the general algorithm, so that valid comparisons and evaluations can be made. (NOAA NWS has indicated that they want to have all aliased wind solutions available for their models.) These competitive methods will be evaluated through the use of SASS ocean measurements on the JPL Algorithm Development Facility (ADF). This computer facility will be linked to the Experiment Team via low-speed interactive terminals and will allow for multiple passes in processing of data from specific sites (Data processing

NOTE: THE NUMBER ABOVE EACH BOX IS AN ABBREVIATED ALGORITHM ID NUMBER. THE NUMBERS BELOW EACH BOX SHOW WHICH I/O OUTPUT ITEMS ORIGINATE FROM EACH BOX. I/O OUTPUT ITEM NUMBERS ARE GIVEN IN IOM 315.6-164, 16 DECEMBER 1977.

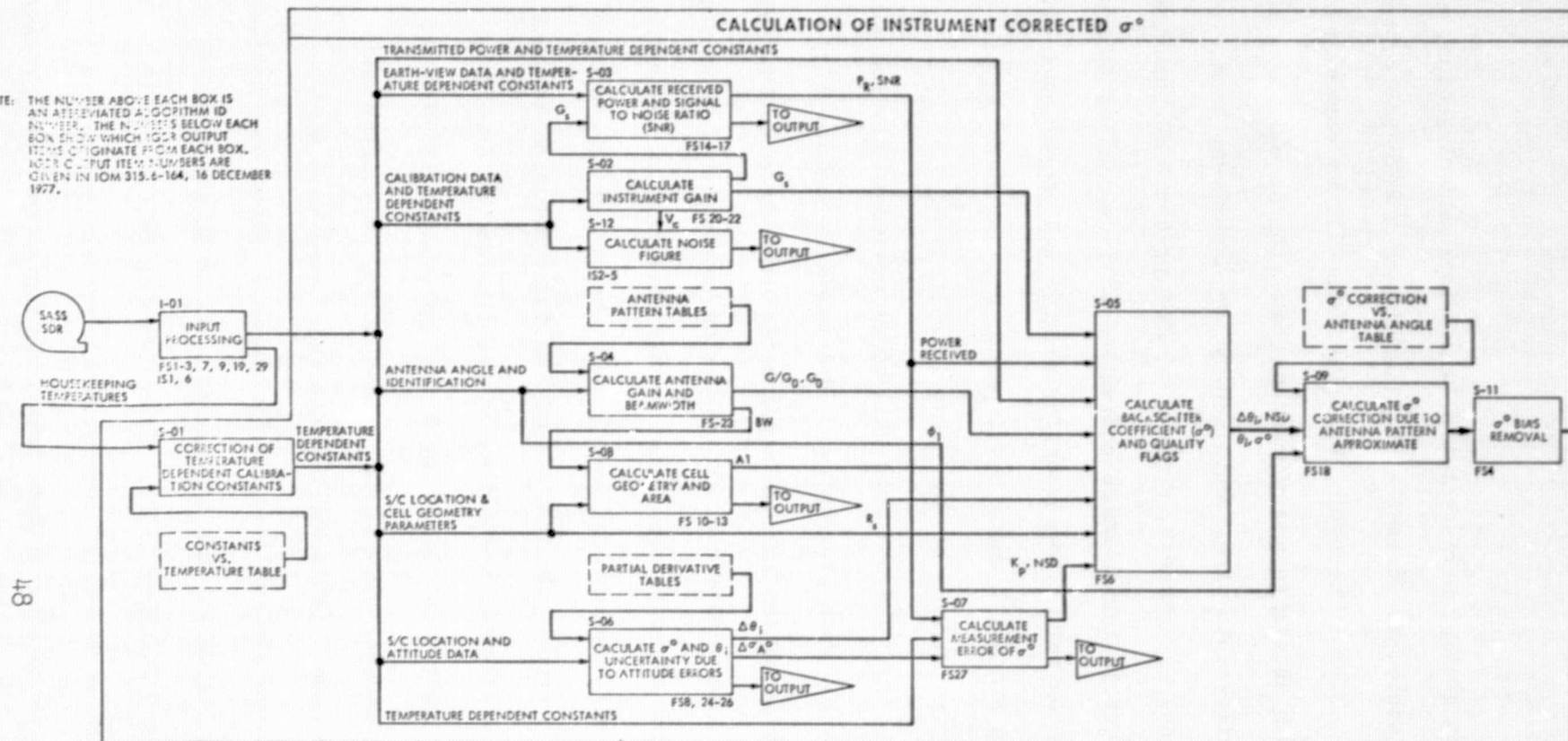


Figure 10.- SASS algorithm flow chart.
(a) SDR to σ

SEASAT-A SCATTEROMETER (SASS) IGDR PROCESSING ALGORITHMS

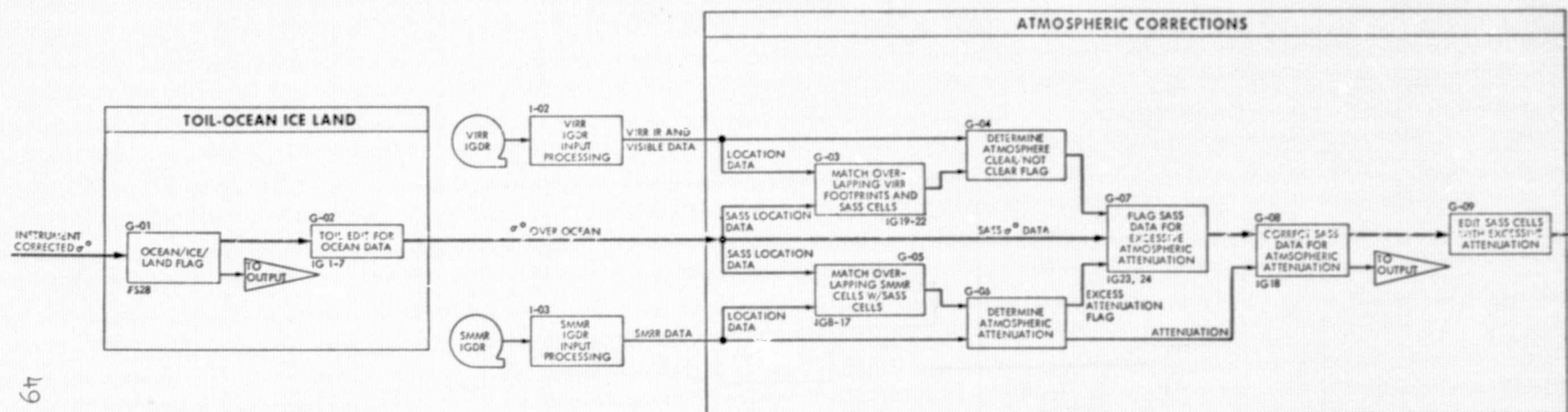


Figure 10.- (Continued)
(b) Atmospheric Correction of σ

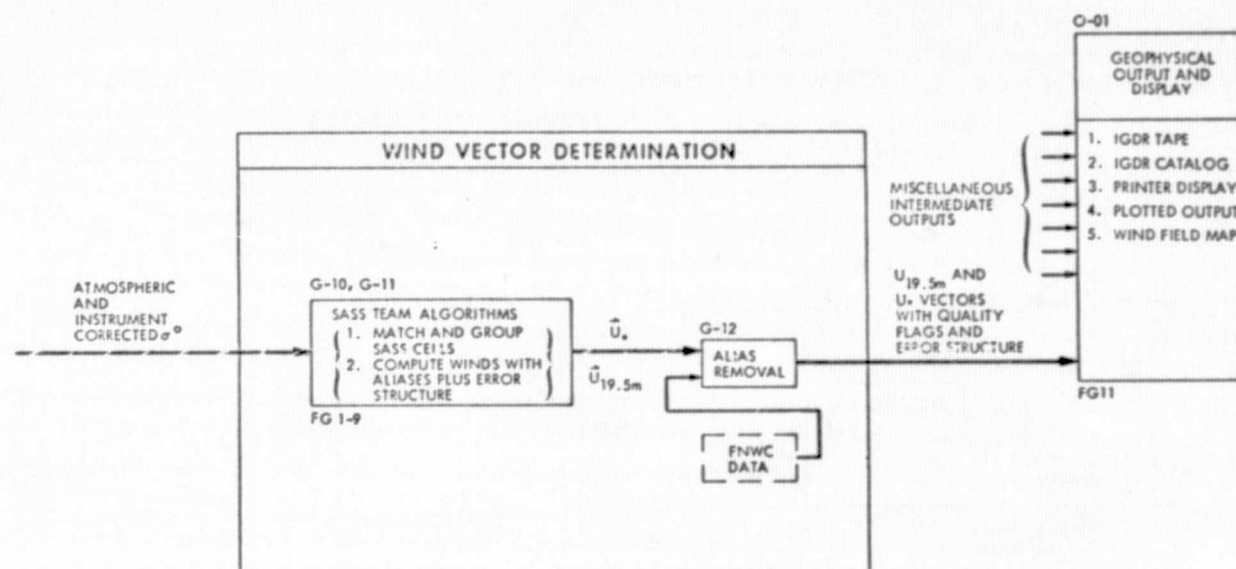
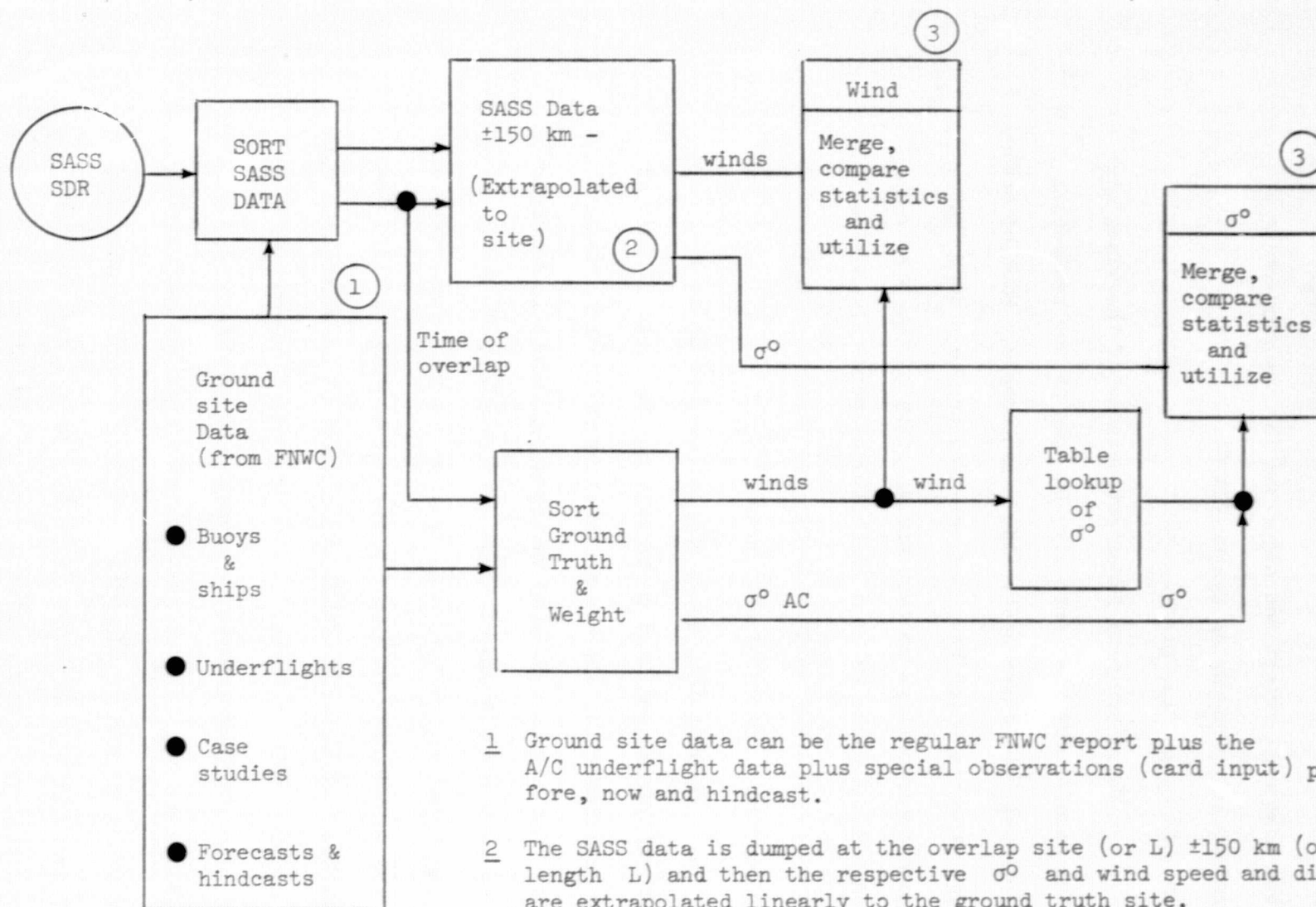


Figure 10.- (Concluded)
(c) Wind calculations



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- 1 Ground site data can be the regular FNWC report plus the A/C underflight data plus special observations (card input) plus fore, now and hindcast.
- 2 The SASS data is dumped at the overlap site (or L) ± 150 km (or some length L) and then the respective σ° and wind speed and direction are extrapolated linearly to the ground truth site.
- 3 Merge means associate all contemporary measured or calculated wind and σ° together with their weights and errors. Compare means to evaluate σ° on a common basis, i.e., if we know winds at ground site we can calculate σ° 's for both fore and aft beams; if we know σ°_{AC} we can compare with σ°_{SASS} at same radar direction.
- 4 All utilizations of the data, - i.e., updating of tables, will be done off line.

Figure 11.- ADF algorithms and functions.

requirements are defined in section 9.4). At the end of the intensive evaluation period the team will select one algorithm for the Project to implement in the Project Data Processing System (PDPS).

7.2.3.2 Ocean Case Studies

There are many important details of the winds over the ocean that can be studied for the first time because of the availability of high resolution, global SASS ocean scattering measurements. Most of these case studies involve phenomena which have been studied to the extent that they also provide good opportunities to test the validity of the wind data generated by SASS. A brief summary of some case studies presently planned is given in the appendix. These studies will be investigated on a non-real time basis using appropriate subsets of SASS data.

In addition, there are believed to be several second order geophysical parameters that contribute to the ocean σ^0 such as gravity wave height and direction, air-sea temperature difference, ocean currents, fetch, etc. The accuracy of wind vector measurements is therefore inherently limited to whatever the sum of these secondary effects are, unless the effects can be accounted for. One task of the Experiment Team is to model these effects to minimize related errors. To accomplish this, the most important requirement is that of establishing a set of baseline data with corresponding high quality surface truth.

Another task is to investigate the use of the SASS for remote sensing of lake and sea ice. The scatterometer provides good spatial and temporal coverage of both the Arctic and Antarctic and will permit ice studies expanded beyond what is presently possible using Nimbus microwave radiometric images. It is the Team responsibility to study (within funding limitations) simultaneous SASS,

SAR and SMMR ice images and to develop algorithms for identifying geophysical parameters such as ice type (age), ridge heights, etc. Special emphasis to obtain satellite measurements simultaneously with on-going aircraft and surface observations is noted.

7.2.3.3 Numerical Weather and Wave Forecasting

The objective of this task is to evaluate the usefulness of SASS wind vector measurements to improve numerical weather and wave forecast. The Experiment Team recognizes that the nature of this task requires FNWC, NOAA NWS/NMC and GSFC cooperation to properly conduct this investigation. The team will provide wind vector algorithms, consultation for use of SASS data with the respective models, and analysis of ground truth. This cooperation is thought to be particularly beneficial for the non-real-time GSFC operations where wind fields may be generated with and without the use of SASS measurements. These calculated winds may then be compared to surface truth observations to provide a large-area evaluation of the SASS measurements. This comparison is felt to be equally important to the single cell comparisons at surface truth sites (section 7.2.3.1).

FNWC and NWS/NMC will conduct a comprehensive off-line test to evaluate the impact of SASS winds on global operational forecast models. If the evaluation shows that the addition of these data to the model data base improves forecast accuracy, every effort will be made to get the SASS winds into the operational models in near real-time.

7.2.3.4 Aircraft Underflights

In order to obtain independent measurements of earth-local conditions near-simultaneously with satellite measurements, a series of aircraft underflight experiments will be flown. Two types of geophysical validation underflights have been identified (see Table VI):

- Wind vector measurement flights, with data obtained using an aircraft scatterometer (SUS) at the same frequency. Conversion of aircraft scattering measurements to wind stress and wind vector would be accomplished using similar inversion procedures as used for SASS. Three flights would be conducted in low, moderate and high wind conditions.

- Low altitude (in-situ) flights to determine local wind vector only (using inertial navigation system). These measurements can be obtained without an aircraft scatterometer and will be required to provide surface truth for targets-of-opportunity such as severe storms.

7.2.3.5 Land Case Studies

The objective of this task is to collect SASS σ^0 data over land and perform limited analysis to identify potential geophysical applications. Potential applications include absolute cross section calibration for SAR, snow coverage identification, water resources survey, soil moisture measurement, and the generation of a σ^0 catalog of various surfaces for design of future radar systems. Again special emphasis will be placed on obtaining satellite measurements simultaneously with on-going aircraft and surface observation programs.

7.3.3 Target Area Characterization

The primary target area is the world's oceans. SASS calibration sites shall consist of NOAA data buoys, U.S. Coast Guard weather ships, and other high quality sources (Ref.5) of in-situ meteorological and oceanographic measurements. A comprehensive list of the locations and capabilities of such sites is given in ref. 5. A listing of available U.S. buoy sites and their locations is given in table VII. The project should make every effort to obtain foreign data sources for use as calibration sites in other part of the world. A large number of calibration sites is essential to this experiment because of the comprehensive data base required for geophysical evaluation. Also the TOIL (Target-Ocean, Ice, or Land) identification is required for each SASS resolution cell to aid in the data interpretation.

Table VII. Status of NOAA Environmental Data Buoy Including Wave Spectrum

CAPABILITY				
BUOY	TYPE	LOCATION (N. LAT./W. LONG)	WAVE MEASUREMENT TYPE	DEPLOYMENT DATE AND/OR STATUS
EB-01	PEB	35.0 / 72.0	2	Operational
EB-03	PEB	56.0 / 148.0	2	Operational
EB-04	NOMAD	26.0 / 90.0	3	Operational
EB-15	PEB	32.3 / 75.3	2	Operational
EB-16	PEB	42.5 / 130.0	2	Redeployed June 1977
EB-17	PEB	52.0 / 156.0	2	Operational
EB-19	PEB	51.0 / 136.0	2	Operational
EB-20	PEB	41.0 / 138.0	2	Operational
EB-21	PEB	46.0 / 131.0	2	Redeployed August 1977
EB-34	NOMAD	40.1 / 73.0	-	Operational
*EB-35	NOMAD	55.3 / 157.0	2	Redeployment data to be assigned
EB-41	CSB	38.7 / 73.6	2	Redeployment to be assigned
**EB-43	NOMAD	59.8 / 142.0	2	Operational
EB-44	NOMAD	26.0 / 86.0	-	Redeployed July 1977
EB-63	NOMAD	40.8 / 68.5	-	Operational
EB-70	MVX 2	59.5 / 142.2	3	Operational
EB-71	MNX 2	26.0 / 93.5	2	Operational
REPLACEMENT FOR OSV HOTEL		38.0 / 71.0	2	Deployed Oct. 1977
XERB		30 / 80	4	EXPERIMENTAL

*To be redeployed (same site) and designated EB-39.

**To be redeployed at a new site and designated EB-45.

Note: Chart will be updated by Ref. 5 and Ref. 6

WAVE MEASUREMENT SYSTEM TYPES: (Wave spectral frequencies available)

<u>TYPE 1 -</u>	<u>TYPE 2</u>	<u>TYPE 3</u>	<u>TYPE 4</u>
.03 to .5 Hz Bandwidth of .01	.05001 Hz .0603 Hz .07017 Hz .07948 Hz .08986 Hz .09951 Hz .12270 Hz .16059 Hz .19820 Hz .24195 Hz .27860 Hz .33180 Hz	.03 to .5 Hz of .005 Hz	Directional Spectra (Experimental)

8.0 EXPERIMENT SUCCESS CRITERIA

The minimum success criterion for this experiment is to demonstrate the all-weather, day/night capability of SASS to meet its oceanographic objectives (section 3.0). Furthermore, the success criteria shall include:

(1) Proof that the ocean scattering coefficient can be measured over the dynamic range and to the accuracy specified in section 5.0.

(2) Proof that geophysical algorithms can be developed which produce the mean, synoptic scale, neutral stability 19.5 m wind vector as specified in section 3.0.

(3) Demonstration that these (geophysical) algorithms can be implemented in a near real-time mode for use in operational numerical weather and wave forecasting models.

(4) Determination of SASS wind measurements that, when combined with conventional meteorological data bases, result in improved weather and wave forecasts.

(5) Proof that the SASS can measure mesoscale strong gradient (magnitude and direction) wind fields such as fronts, tropical cyclones, and hurricanes.

9.0 MISSION REQUIREMENTS

9.1 Orbit Parameters and Spacecraft Characteristics

See sections 4.2.1 and 4.2.2 for Orbit parameters and reference 7 for Spacecraft Characteristics.

9.2 Operations

Post-launch operations will be coordinated by an Experiment Team member assigned to the JPL Mission Planning Team. His responsibility will include assessing the ongoing mission profile, and determining the SASS

experiment data gathering operations. In general, the activities will be carried out as described in the SeaSat A Mission specification document.

Pre-launch and post-launch operations shall also include aircraft operations. Flights will be conducted in the SASS measurement swath in the Atlantic and Pacific Oceans, and in the Gulf of Mexico. Prime data collection is for the period 1 hour prior to and 1 hour after the satellite pass. As a secondary period, data will be collected on the return trip. When possible, flights will be coordinated so that the aircraft overflies a NOAA buoy or USCG weather ship.

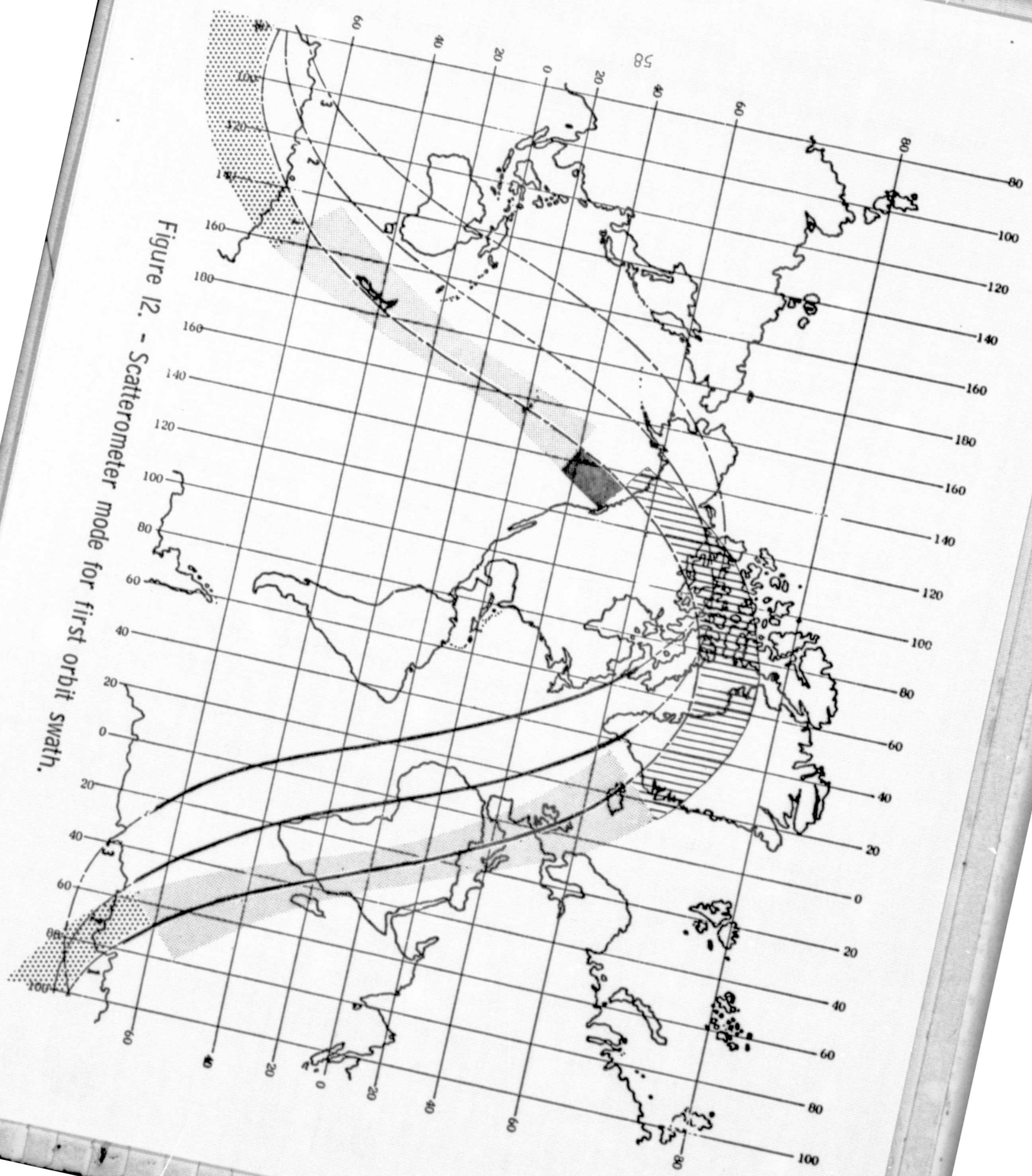
9.2.1 Typical plan of SASS Operation

The Experiment Team has defined typical SASS operating sequences as an aid to the Project's mission planning effort. This typical operating plan is intended to provide the baseline or default mode of SASS operation from which changes and updates will be made by the SASS mission planner. The following gives SASS modes and the corresponding earth coverage for six orbits. The rationale for generating these sequences are:

1. Mode 1 or 2 (V or H polarization, left and right side measurement swaths) to be used over open ocean.
2. Mode 3 or 4 (V and H polarization, left or right side) to be used over calibration sites or over ocean where other side swath is over land.
3. Mode 6 or 8 (V or H polarization, right side) to be used over Arctic region.
4. Mode 5 or 7 (V or H polarization, left side) to be used over Antarctic region.

Figures 12 through 17 give the results of this analysis in plan view. The preliminary Sattrk calculator was used to locate these orbits, and these results can be extended to additional orbits easily.

Figure 12. - Scatterometer mode for first orbit swath.



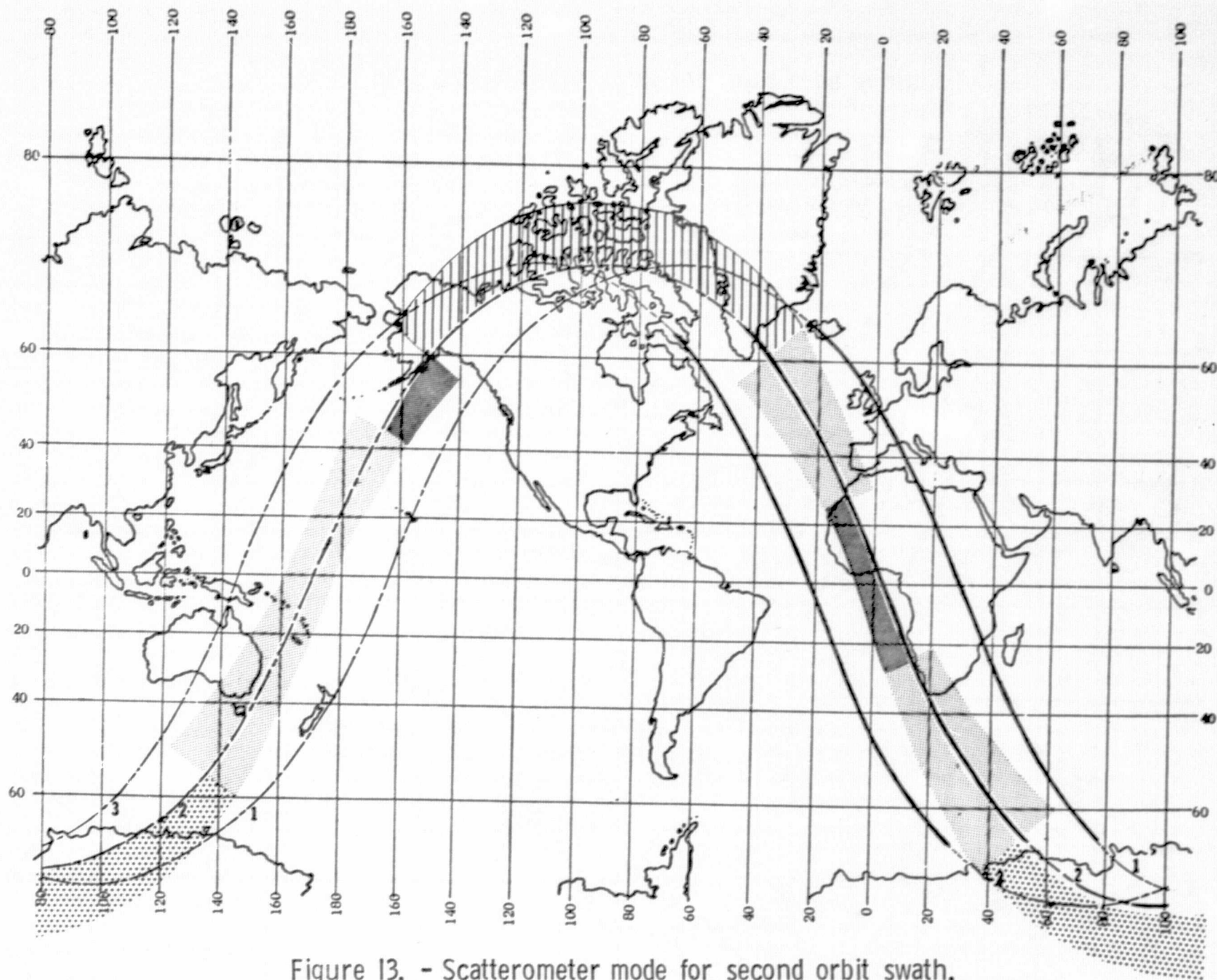


Figure 13. - Scatterometer mode for second orbit swath.

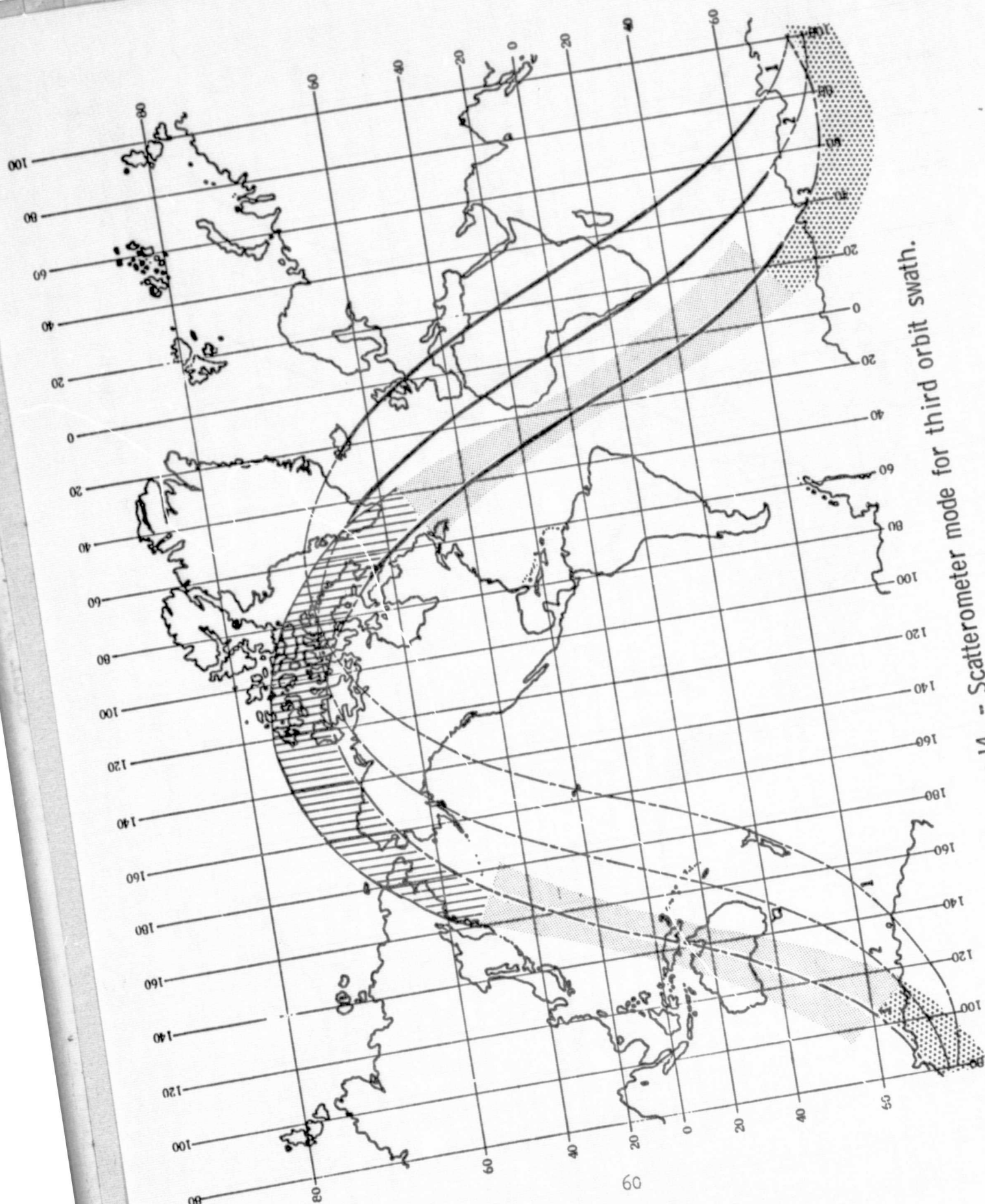


Figure 14. - Scatterometer mode for third orbit swath.

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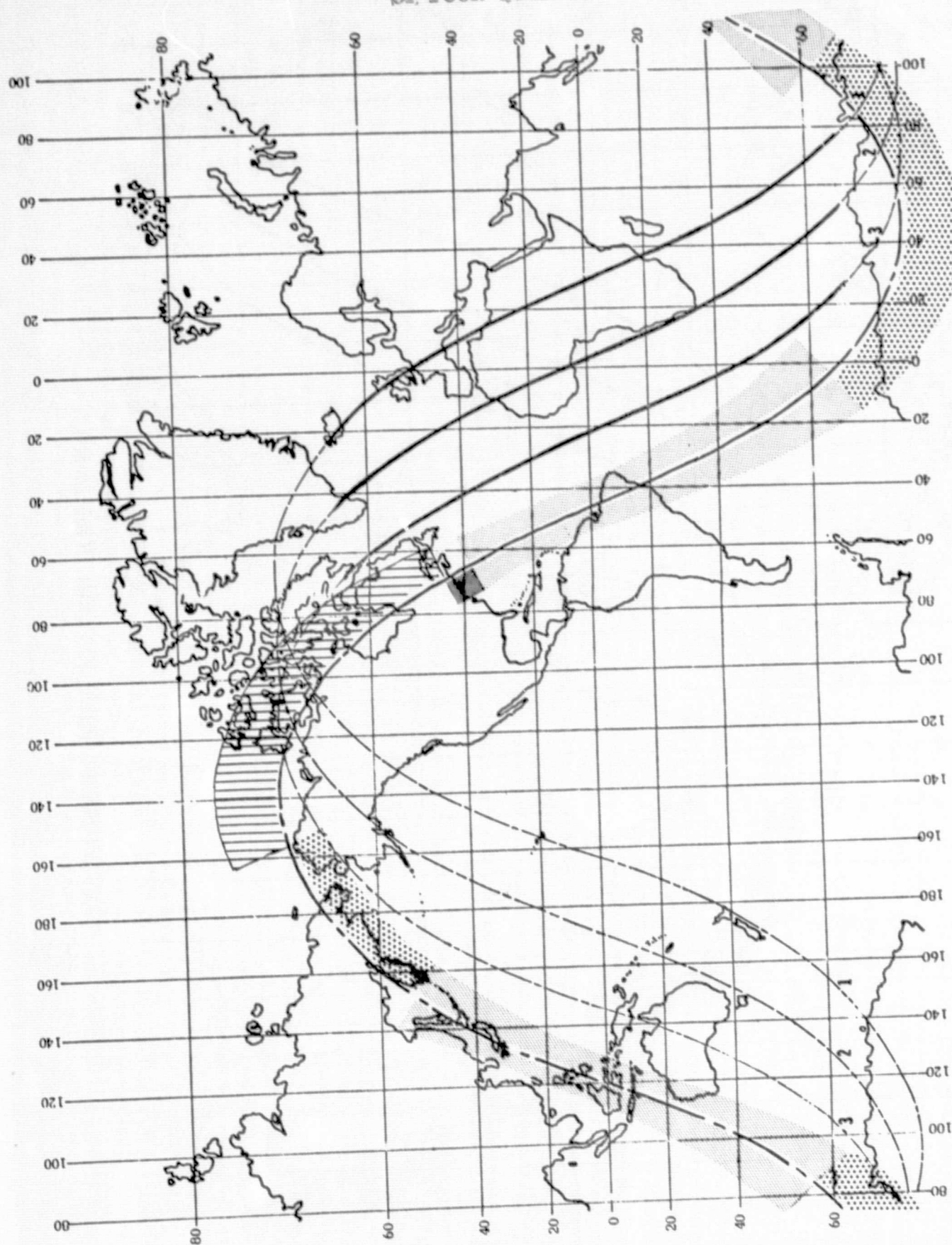


Figure 15. - Scatterometer mode for fourth orbit swath.

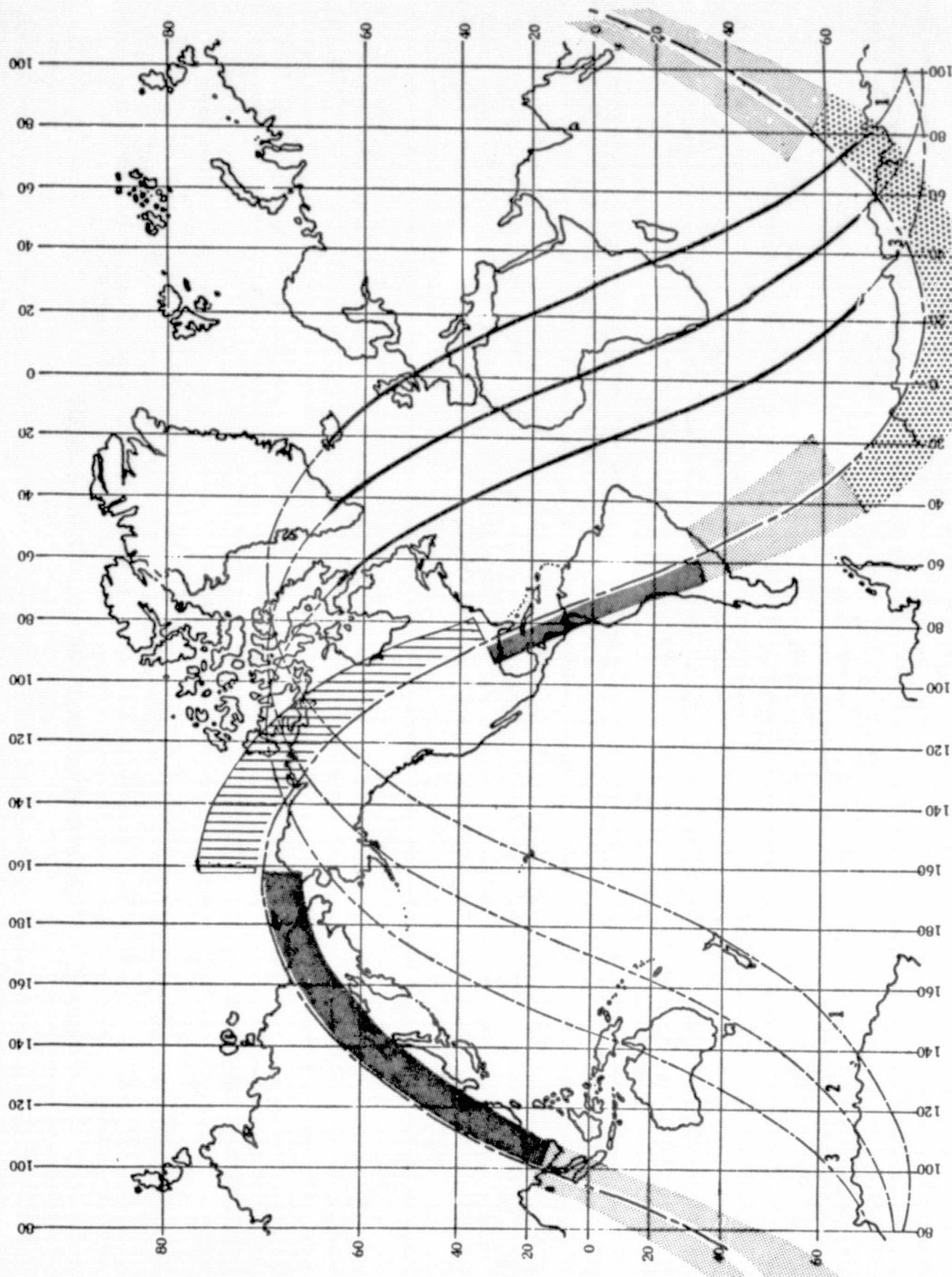


Figure 16. - Scatterometer mode for fifth orbit swath.

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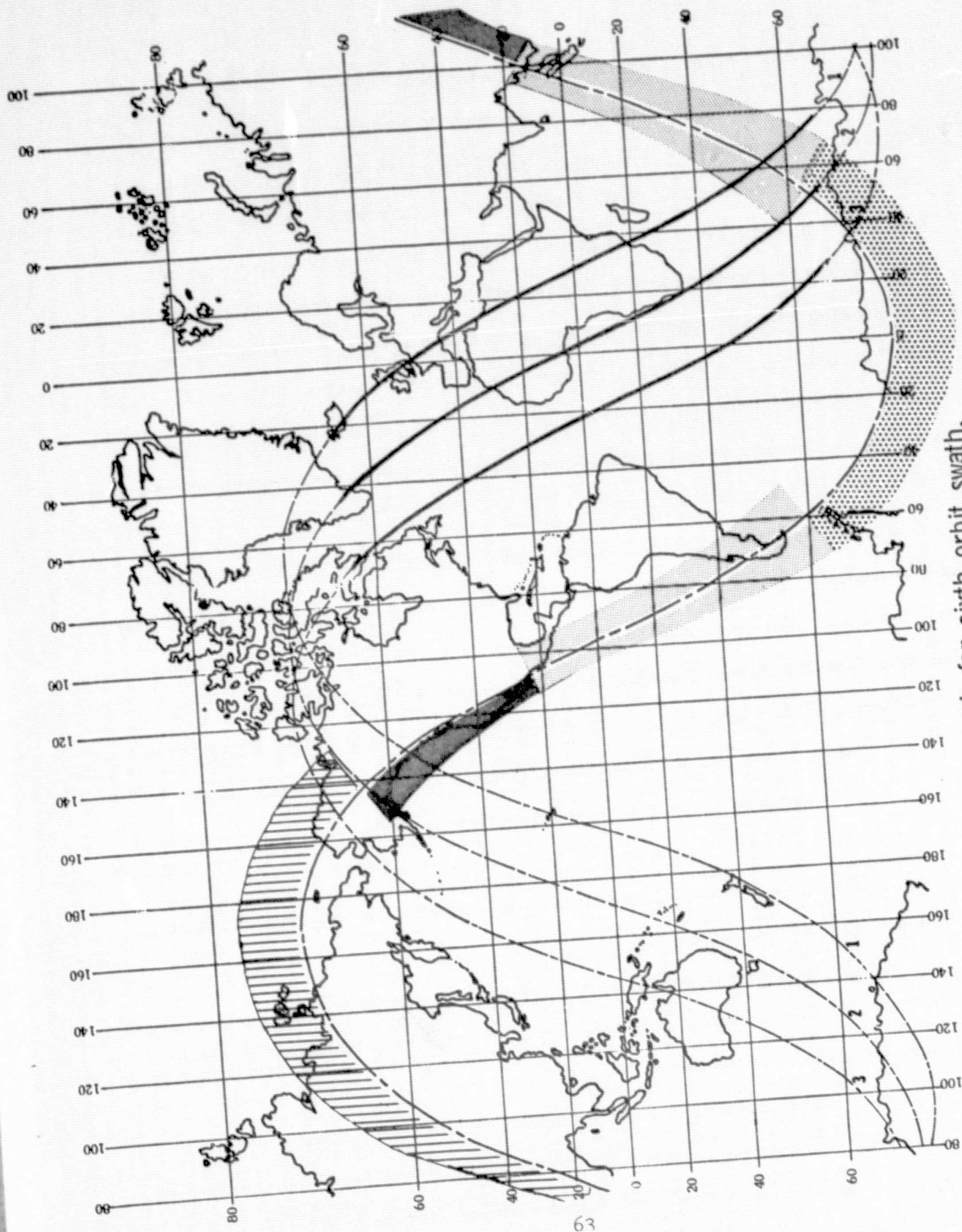


Figure 17. - Scatterometer mode for sixth orbit swath.

9.2.2 Final plans for SASS operation.

The SASS Mission Planner will incorporate requests of Experiment Team members, ASVT users, the Sensor Implementation Manager, and the Project into the final SASS operating plan, according to the Evaluation Task Group plan priorities and goals. These plans will be made for a one month period and updated weekly. Generally, therefore, the last opportunity for changing the SASS operating plan is one week before the event. It will be possible, however, to effect a change in the SASS operation as late as 1 day before the event, but only for matters of extreme importance such as rare occurrence of a priority target of opportunity or spacecraft trouble diagnostics.

9.3 Algorithm Development

It is the purpose of this paragraph to describe the technical plans and procedures required to transform the measurements made by the SASS instrument into the data form necessary for analysis by the various experiments. The data flow for these plans are shown in figure 10 for production of the IGDR (items (1) through (5)) and in figure 11 for ADF activities (Item (6)).

These tasks can be categorized generally in the following manner:

- (1) Conversion of satellite measurement SDR's into earth-located and coordinated normalized scattering cross sections (NRCS's or σ^0 's).
- (2) Trail flagging, merging with Altimeter data and separating ocean σ^0 's from land and ice σ^0 's.
- (3) Atmospheric attenuation correction of ocean σ^0 's.
- (4) Conversion of corrected ocean σ^0 's into surface wind stress and neutral stability wind vectors.
- (5) Generation of the Geophysical Data Records.
- (6) Algorithms required for geophysical evaluation, such as merging of SASS data with surface truth and auxiliary data (aircraft underflight σ^0 's, FNWC data, etc.).

9.3.1 SDR to σ^0 . The algorithms required to complete this test (as currently understood) are identified by the blocks in this "module" of figure 10. Each of these blocks have been investigated extensively by LaRC, and coding for most cases exist in some form.

9.3.2 Toil flagging, Altimeter data merge, and σ^0 data separation by ocean or ice & land. Experiment Team requirements include:

- (1) Toil
- (2) Alt Data - σ^0 merge
- (3) Separate out ocean σ^0 data
- (4) Generate land and ice σ^0 file

The Toil flagging algorithm is a JPL responsibility. It is understood that only the algorithm software shown in figure 10(b) will be generated by the Project.

9.3.3 Atmospheric correction of the ocean σ^0 's. This algorithm for atmospheric correction using the SMMR, along with the science to support it, is being developed by the University of Kansas, with assistance from Jones and Kline¹ of LaRC, and Woiceshyn of JPL. The atmospheric attenuation is computed using the brightness temperatures obtained from prepared SMMR grids² overlapping the SASS resolution cell. Only vertical polarization measurements at 6.63, 10.69, 18.00, and 37.00 GHz are used in the technique.

SMMR measurements are made at a nominal incidence angle of 49° from normal. At this incidence angle, vertical polarization measurements are nearly independent of surface roughness effects. This allows the brightness temperature of the surface to be approximated by the product of the surface temperature and the emissivity of a smooth sea surface. The

¹Larry Kline is now with Honeywell.

²Produced by JPL.

difference between the measured and this "true" brightness temperature is defined as the excess brightness temperature. This quantity is completely dependent upon atmospheric parameters.

Vertically polarized excess brightness temperatures at 10.69, 18.00 and 37.0 GHz and the atmospheric attenuation at 14.6 GHz have been calculated using radiative transfer and various atmospheric attenuation, cloud and rain models. The results appear to be model independent and a power series through the third order appears to relate these quantities.

The SASS attenuation is estimated by the computed average of all SMMR cells centered within the resolution cell. Weighting is done by both distance and frequency (sensitivity).

During the Geophysical Evaluation, SMMR team outputs of rain rate, non-precipitable liquid water, and water vapor will be obtained on a periodic test basis. Using these data, an independent prediction of atmospheric attenuation can be obtained for comparison.

Since the SMMR scans only 600 km right of the satellite subtrack, it cannot be used directly to provide attenuation estimates for the outer SASS cells on the right side and the entire left side of the spacecraft. Originally VIRR outputs were to be used for this purpose, but the science and resources needed for this task were not available. It is assumed that the resources to develop the techniques to use the VIRR will be available during the evaluation period.

One of the most promising employs a correlate matrix created when both VIRR and SMRR are on the same track. Here, attenuation calculated from SMMR-derived rain rate, liquid water, and water vapor parameters is compared with VIRR IR brightness temperature and normalized radiance. Different correlate

matrices will exist for approximately each 100 km of ground track (latitude dependent matrices). The VIRR temperature and radiance measured when VIRR is on the opposite track from SMMR would then be input parameters to the matrix, while attenuation is the output parameter.

However, estimating the attenuation using the VIRR is not the only problem with its use. A computer-efficient algorithm must also be developed to handle the monstrous quantities of data it outputs. The algorithm must combine the VIRR measurements to reduce the necessary range, while maintaining a fine enough resolution to distinguish areas of rain.

9.3.4 Ocean σ^0 to winds. This task accepts the ocean σ^0 file corrected for atmospheric effects as input and converts it into frictional wind velocity and neutral stability wind. Three separate models are used to convert to winds. Preliminary ADTG algorithm specification sheets have been provided to the Project by the algorithm sponsors for each case and the following algorithms have been identified for the CUNY algorithm:

(1) SASS cell Co-location (SCC) - For each (on each side) SASS cell in the beam with the widest swath, finds the cell for the beam with the narrowest swath that is closest to it (and if needed, the next closest).

(2) Wind Vector probability contours - constructs a curve in wind vector space that has a FIDUCIAL probability of p (= 0.5, 0.9, or as desired) of enclosing the true vector wind.

(3) Vector wind plus aliases - determine best estimate for zero to four vector winds for any close pair of SASS co-located cells from (1) above.

(4) Alias Elimination-Vector wind field recovery - eliminates aliases from set of vector winds and prints out true vector wind field.

The following U of Kansas algorithms have been identified:

(1) SASS Cell Colocation - This algorithm matches fore- and aft beam cells which have footprints within a given geographical area (similar to (1) above. It can be operated so only the closest cells are found for fine resolution, or multiple cells within a pre-assigned distance for coarse resolution.

(2) WINDVEC. Provides estimates of wind speed and direction at the midpoint of matched SASS measurements.

(3) UPGRADE. Provides for calculating and inserting new values of U. of Kansas model coefficients based on SASS results over surface truth sites. (A similar subroutine is expected for Wentz and CUNY models).

(4) MLIKLY. When both the HH and VV measurements are available, an ordering of the wind vector solutions is made by likelihood techniques.

(5) PROBAB. Assigns a probability to the wind vector solutions

The following Wentz algorithms have been identified:

(1) GROUP. Sets up an Earth-fixed grid bins and locates, stores and outputs all SASS cells within these bins on passage of the aft antenna beams.

(2) WINVEC. Does a coarse search in the probability space (computes U_{*} with aliases) by interpolation of a table of NRCS vs geophysical parameters. Then in the locality of the maxima, does a bivariate Gaussian fit (calculates relative probabilities and error structure).

(3) WINTRU - Finds the true wind vector from the list of aliases.

The final algorithm is:

Compute $\vec{U}_*$, $\vec{U}_{10}$ and $\vec{U}_{19.5\text{ m}}$ and associated errors. This algorithm takes the output of the three wind vector algorithms and does the indicated calculations. This algorithm is presently not assigned and no ADWG specification sheet has been written.

9.3.5 Generation of the Geophysical Data Records. This task is the responsibility of the project. However, the necessary files are shown being generated on figure 10 or can be obtained by special processing. The files, which have been requested consist of:

- (1) σ^0 file
- (2) σ^0 ocean corrected file
- (3) σ^0 land & ice file
- (4) SASS near-nadir σ^0 and ALT σ^0 file
- (5) Wind vector (high spatial resolution)
- (6) Wind vector (low spatial resolution)

The desired contents of these files as requested by the Experiment Team are given in Section 9.4.1.3.

9.3.6 Algorithms required for Geophysical Evaluation. This task consists of sorting through the SASS GDR's for data which coincide with data obtained from insitu and aircraft underflights and comparing and merging the σ^0 's and winds from all sources. The comparisons will provide a systematic check of the accuracy of the SASS and its algorithms; and help to assemble a much more comprehensive data bank for the SASS. The data flow chart with all functions required for this task that have been identified to date is shown in figure 11.

9.4 Analysis of Mission Results

9.4.1 Experiment Data Processing

The SASS data will be formatted (block telemetry), transmitted to the STDN ground receiving stations, and relayed to NASA Goddard Space Flight Center (GSFC) TELOPS Facility for development of the Telemetry Master Data File (TMDF). The TMDF is a complete record of the SeaSat A low rate telemetry stream (25 kbps), but does not include the high rate analog SAR data stream. It is delivered to the Project Data Processing System (PDPS) approximately 3-5 days after receipt at GSFC. Subsequent processing will be accomplished in the following ways.

9.4.1.1 PDPS Processing

Data processing at JPL begins in the PDPS with TMDF as an input and the Sensor Data Record (SDR) as the first processed data output. After a suitable engineering evaluation period (using the SDR), the SDR will be available for use in subsequent geophysical processing. It is the Experiment Team's desire that the SDR contain the following information:

- (1) Time
- (2) TM data converted to engineering units (volts, temperatures, and status bits and a flag indicating SASS data quality).
- (3) Cell location parameters for the center of each cell
 - (a) Latitude (geocentric)
 - (b) Longitude (geocentric)

- (c) Slant range
- (d) Incidence angle (geodetic)
- (e) Cone angle
- (f) Clock angle from subtrack
- (g) Base length of Doppler cell
- (h) Angle between Doppler direction and
maximum antenna gain direction
- (i) Azimuth angle from true North
- (j) Antenna identification and cell number
- (4) Satellite Location information
 - (a) Latitude
 - (b) Longitude
 - (c) Satellite ground velocity along track
 - (d) Direction of satellite in orbit
 - (e) Spacecraft attitude control uncertainty
 - (f) Orbit number

9.4.1.2 ADF Processing

The purpose of the JPL Algorithm Development Facility (ADF) is to provide algorithm and software development support for sensor validation and geophysical evaluation. This facility shall consist of the Univac 1108 computer at JPL and shall be linked to the Sensor Implementation Manager and Experiment Team by low-speed interactive remote terminals (located at NASA Langley Research Center, City University of New York, and University of Kansas). The use of the ADF by the Sensor Implementation Manager and the Experiment Team for the post-launch activities is illustrated in figure 11. The ADF will consist of, but not be limited to, the computer

algorithms identified in section 7.3 and the ADTG specification sheets to be published as a supplement. A summary of the general categories is given in the following: (organization responsible for and development status are given in parenthesis)

(1) Received power (Bracalente - LaRC, near complete) - converts the SASS integrator output voltage to received power. This program is also a subroutine in the Scattering Coefficient Algorithm.

(2) Scattering Coefficient (σ^0) (Bracalente - LaRC; near complete) - uses spacecraft and orbit data to calculate the scattering coefficient for each SASS cell (σ^0 uncorrected for atmospheric effects).

(3) Atmospheric Correction (Moore - U of K; definition only) - uses SMMR and other data to calculate the atmospheric attenuation and to locate probable rain cells. Attenuation calculations using the VIRR data have been scoped, but have not been undertaken by anyone due to a lack of resources.

(4) Wind Vector - (Three algorithms; (1) Wentz - LaRC; partially complete; (2) Pierson - CUNY partially complete; (3) Moore - U of K, partially complete) uses atmospheric corrected scattering coefficients from SASS forward and aft antennas to calculate the ocean surface vector wind and wind stress.

(5) SASS Cell Prediction (LaRC, Bracalente definition complete; JPL responsibility to develop)

(a) Given latitude and longitude, uses the predict orbit to calculate orbit number, time, and SASS incidence/azimuth angles for this location.

(b) Given time, uses the predict orbit to calculate latitude and longitude for each SASS cell.

(6) SeaSat A Catalog - (JPL responsibility - defined) a catalog file for all SDRs (tape number and pertinent identification).

(7) Catalog Search (JPL responsibility - defined)

(a) Time Search - searches catalog for given time segment for specified sensor data.

(b) Geographical Search - searches catalog to locate specified sensor data for a given geographical location.

(8) Tape Search - searches given SDR and extracts specified sensor data (JPL responsibility - status unknown).

(9) Toil Identification - uses earth located sensor footprints to classify surface as ocean, ice, or land. (JPL - defined).

(10) Surface Truth/IGDR Data Bank - a permanent file for storing "surface truth" and associated IGDRs for SASS, SMMR, and V & IR (LaRC defined, JPL responsibility - status unknown).

The SIM/ET shall have direct access to all computer programs (permanent files) and shall be permitted to create modified versions on temporary files, as required for the sensor validation and/or geophysical evaluation. All permanent files shall be under strict change control by JPL.

9.4.1.3 Interim Geophysical Data Record (IGDR)

Final definition of the IGDR is not presently possible; in general, however, it is recommended that they consist of the following files of data records each preceded by a header. The project has indicated that they do not expect to fund the files as indicated. Rather, they have agreed to provide routinely only all SASS measurements converted to σ^0 values, uncorrected for atmospheric effects. Approximately 3-5% of all data will be processed to validation and geophysical evaluation products; ie, atmospheric-corrected σ^0 and winds. Also, the project intends to fund processing beyond the routine σ^0 only if the products evaluate the SASS

capabilities to achieve objectives. For this reason, some of the data files (3 and 4) cited and some of the case study data will not be produced unless funding sources outside the Project are obtained. In addition, it is understood that the Project may not be able to supply routinely the files in the formats listed; however, the Experiment Team does expect all elements of these files to be stored and merging routines supplied by the Project so that these files can be generated routinely on the ADF. In general, all of these requirements are expected to be provided by JPL (see JPL Interoffice Memorandum 315.6-164, dated Dec. 16, 1977 and SASS parts revised in March 1978), except for Altimeter σ^0 . These files contain the following:

(1) σ^0 File

- Header:

- (a) Mode
- (b) Orbit number
- (c) Current calibration values
- (d) Instrument transfer function constants
- (e) Gain quality flag
- (f) Noise figure

- Data Record Elements

- (a) Observation time
- (b) Cell location (latitude and longitude of center of SASS cell* and standard deviation (km) of cell location error and azimuth orientation of the error direction)
- (c) Doppler cell number
- (d) Beam number
- (e) Polarization

*Unless otherwise noted, SASS cell refers to the resolution cell. See reference 3, figure 8.

- (f) mean incidence angle and standard deviation (degrees)
 - (g) Antenna look angle (azimuth relative to true North) and standard deviation (degrees)
 - (h) Slant range (to center of cell)
 - (i) Cell size (area and rectangular dimensions)
 - (j) Doppler cell length (parameter L used in σ^0 calculation)
 - (k) Antenna gain (G)
 - (l) Transmitted power
 - (m) Received power (estimate and standard deviation)
 - (n) Signal-to-noise ratio
 - (o) Scat channel number
 - (p) Scat channel gain with and without noise
 - (q) σ^0 (uncorrected for atmosphere) and normalized standard deviation (dB) (separated into elements)
 - (r) TOIL flag (percent ocean, land, and ice)
 - (s) Data quality flag (multi. flag)
 - (t) Switching matrix loss
- (2) Ocean σ^0
- Header:
 - (a) Mode
 - (b) Orbit number
 - (c) Current calibration values
 - (d) Instrument transfer function constants
 - Data Record Elements
 - (a) Observation time

(b) Cell location (latitude and longitude of center of SASS cell and standard deviation (km) of cell location error and azimuth orientation of the error direction)

(c) Doppler cell number

(d) Beam number

(e) Polarization

(f) Mean incidence angle and standard deviation (degrees)

(g) Antenna look angle (azimuth relative to true North) and standard deviation (degrees)

(h) Slant range (to center of cell)

(i) Cell size (area and rectangular dimensions)

(j) Doppler cell length (parameter L used in σ^0 calculation)

(k) Antenna gain (G)

(l) Transmitted power

(m) Received power (estimate and standard deviation)

(n) Signal-to-noise ratio

(o) Scat channel number

(p) Scat channel gain with and without noise

(q) Ocean σ^0 (uncorrected for atmosphere) and normalized standard deviation (dB) (separated into elements)

(r) TOIL flag (percent ocean, land, and ice)

(s) Data quality flag (multidimensional)

(t) Switching matrix loss

- (u) VIRR brightness temperatures (co-located with SASS cell)
- (v) SMMR brightness temperatures (co-located with SASS cell)
- (w) Altimeter normalized scattering coefficient (σ^0)(co-located with SASS cells)
- (x) Atmospheric attenuation at 14.6 GHz
- (y) Atmospheric attenuation source (relative weight of SMMR, VIRR, and other data)
- (z) Atmospheric corrected scattering coefficient and normalized standard deviation (dB)
- (3) SASS near-nadir σ^0 and Alt. σ^0 file
 - Header:
 - (a) Mode
 - (b) Orbit number
 - Data Record Elements
 - (a) Observation time
 - (b) Cell location (latitude and longitude of center of SASS cell and standard deviation (km) of cell location error and azimuth orientation of the error direction)
 - (c) Doppler cell number
 - (d) Antenna number
 - (e) Polarization
 - (f) Mean incidence angle and standard deviation (degrees)
 - (g) Antenna look angle (azimuth relative to true North) and standard deviation (degrees)

(h) Scattering coefficient for cells 13, 14, 15 only (uncorrected for atmosphere) and normalized standard deviation (dB) (separated into elements)

(i) TOIL flag (percent ocean, land, and ice)

(j) Altimeter normalized scattering coefficient (σ^0)(co-located with SASS cells)

(k) Altimeter height ($h^{1/3}$) (colocated with SASS cells)

(l) SASS polarization angle relative to North

(m) Altimeter polarization angle relative to North

(4) Land and Ice σ^0 File

• Header:

(a) Mode

(b) Orbit number

• Data Record Elements

(a) Observation time

(b) Cell location (latitude and longitude of center of SASS cell and standard deviation (km) of cell location error and azimuth orientation of the error direction)

(c) Doppler cell number

(d) Antenna number

(e) Polarization

(f) Mean incidence angle and standard deviation (degrees)

(g) Antenna look angle (azimuth relative to true North) and standard deviation degrees)

(h) Cell size (area and rectangular dimensions)

- (i) Scattering coefficient (uncorrected for atmosphere) and normalized standard deviation (dB) (separated into elements)
- (j) data quality flag
- (k) TOIL flag (percent ocean, land, and ice)
- (l) VIRR brightness temperatures (co-located with SASS cell)
- (m) SMMR brightness temperatures co-located with SASS cell
- (n) Altimeter normalized scattering coefficient (σ^0)(co-located with SASS cells)
- (o) SASS polarization angle relative to North
- (p) Altimeter polarization angle relative to North
- (5) High and Low Spatial Coverage Wind Vector File
 - Header
 - (a) Orbit number
 - (b) Observation start time
 - (c) Limited identification (date this record produced, SDR identification, geophysical algorithm identification, etc.)
 - Data Record Elements
 - (a) Mean resolution cell location (latitude and longitude)
 - (b) Number of cells used
 - (c) Cells identification (antenna number, polarization, Doppler cell number, etc.)
 - (d) Mean scattering coefficient and normalized standard deviation for above (individual cells)
 - (e) Multiple solution - mean wind vector (MWV) and vector error contour (VEC)

(f) TOIL flag (percent ocean, land, and ice)

(g) Data quality flag

9.4.1.4 Near Real-Time Processing

A selected portion of the data is planned to be transferred directly from STDN stations to the Navy's FNWC facility for near real-time use in their weather forecasting models. This use of scatterometer data is expected to provide a demonstration of the impact of availability of extensive weather inputs over the sea. It is imperative that the algorithms used at this facility be identical technically with those to be available and used at the ADF so that data analysis can be done in a consistent manner.

10.0 DATA REQUIREMENTS

Because of the advanced date of this report, a document is already under preparation which discusses in detail JPL's proposal for providing SDR data (reference 10). This document will be reviewed by the Experiment Team, and concurrence will indicate that it satisfies Experiment Team requirements. Additional requirements resulting from this review will be forwarded to JPL.

10.1 Sensor (TBD)

10.2 Experiment

10.2.1 Imagery Data

Limited SAR and VIRR imagery is required for the non-real time geophysical data analysis. It is understood that the SAR data will be obtained via the SAR Experiment Team and will be restricted to those data otherwise required by the SAR team.

10.2.2 Digital Data

All data should be in digital form and formatted in the most expeditious way for co-locating the data from all the instruments at each cell scanned by SASS. (See section 9.4).

10.2.3 False Color Displays *

Daily global and some regional false color displays of SASS σ^0 and winds are required for both the sensor validation and the geophysical evaluation activities. Formats and detailed specifications are TBD.

10.2.4 Auxiliary Data

Spacecraft and orbit data requirements are defined for the SDR (section 9.4.1.1). Other auxiliary data requirements are as follows.

10.2.4.1 Other SeaSat A Sensors

Auxiliary data are required from the VIRR, SMMR, ALT, and SAR. These data (except SAR) shall be co-located with the corresponding SASS resolution cell. For VIRR, SMMR, and ALT, these data shall be included in the IGDR (section 9.4.1.3).

(1) VIRR - Brightness temperature in absolute units at both wavelengths

(2) SMMR - Brightness temperature in absolute units at all wavelengths and polarizations

(3) SMMR - Atmospheric attenuation at 14.6 GHz

(4) SMMR - Rain rate

(5) ALT - Nadir σ^0

(6) ALT - Significant wave height

(7) SAR - Radar Images of selected targets

(primarily over ice and land).

*(Not in present Project plans; perhaps in FY '79.)

10.2.4.2 Surface Truth

Auxiliary data are required from conventional meteorological and oceanographic sources as well as special SeaSat A Surface Truth Measurement sources. The preferred data sampling period is ± 1 hour to the satellite passage. Hourly measurements are desired (or more often, if routinely provided). Parameters of interest are:

- (1) Mean wind speed and direction (20 min averages) and normalized standard deviation
- (2) Air temperature
- (3) Sea temperature (skin, bucket, and intake)
- (4) Specific humidity
- (5) Atmospheric pressure
- (6) Wave spectra
- (7) Significant wave height
- (8) Rain rate
- (9) Cloud type, percent coverage, and estimated height

It is anticipated that these data will be collected by FNWC and provided to the Project for distribution to the SASS experiment team in a timely manner for validation and evaluation purposes.

10.2.4.3 Numerical Weather and Wave Calculations

Limited weather and wave forecasts and/or hind casts are required from NOAA-NWS, FNWC, and GISS for geophysical evaluation. These will be standard output products for the above facilities.

10.2.5 Bad SASS Data

Bad data for any reason such as dropped bits or poor reception at the ground telemetry station shall be identified and promptly discarded for each 1.89 second data period affected.

10.2.6 Data Availability and Distribution

All SeaSat A low-rate sensor data and auxiliary data shall be cataloged in the ADF. A limited amount of these data (3 - 5 percent) will also be processed by the ADF for use in the sensor validation and geophysical evaluation activities. Computer resources (hardware and software) shall be supplied by JPL to support the Sensor Implementation Manager and the Experiment Team in these tasks (see section 9.4.1.2). Low volume data distribution will be accomplished by either the low-speed remote terminals, or by mail. High volume data distribution will be accomplished through the use of computer compatible tapes or listings delivered by mail.

11.0 ORGANIZATION AND RESPONSIBILITIES

11.1 Sensor

The reader is referred to the Sensor Implementation Plan (SIP, reference 11) for detailed description of organization and responsibilities related to the sensor development.

11.2 Experiment

The organization of the Experiment Team and its responsibilities, including the definition of the experiment, the analysis of the data and reporting obligations, are outlined in a Memorandum of Understanding between the SeaSat A Project and the SASS Experiment Team (TBD). A list of the Experiment Team members is given in Table VIII, and a summary provided by Lane (JPL) of responsibilities between the Project, Sensor Implementation Manager, and the Experiment Team is given in Table IX.

11.3 Inter-Team

A listing of the responsibilities between the SASS Experiment Team and the other SeaSat A Sensor Teams is given in Table X. Excluded from this table are the data exchanges which are described in sections 9.0 and 10.0.

Table VIII. Experiment Team Members

As of the Feb. 22-23, 1978 meeting, the following are or have been nominated to be members of the SASS Experiment Team:

<u>Member</u>	<u>Organization</u>	<u>Phone</u>
W. J. Pierson, Chairman	CUNY-Inst. of Marine Science	(212) 690-8315
W. Linwood Jones, Scientist	NASA - LaRC	(804) 827-3631
William L. Grantham, Sensor Manager	NASA - LaRC	FTS 928-3631 (804) 827-3631
Peter G. Black	NOAA-NHEML	(305) 666-4614 FTS 350-4270
Jack Ernst	NOAA-NESS	FTS 763-8087
Glen Flittner	NOAA-NWS	(301) 443-8734
Andy Goroch, designee*	USN-NEPRF	(408) 646-2837
Lawrence Gray	Canada - Remote Sensing Center	(613) 998-9060
<u>or</u> Steve Peteherych	AES - Canada	(416) 667-4815
I. Halberstom	JPL	(213) 354-2394 FTS 792-2394
Kumar Krishen	NASA-JSC	FTS 525-2666
Ledoph Baer <u>or</u> Pat DeLeonibus	NOAA-Hq	(301) 443-8734
Cmdr. Bill Maxwell	USN FNWC	(408) 646-2817
R. K. Moore	U. of Kansas, CRES	(913) 864-4836
Frank J. Wentz	Wentz Associates	(415) 957-1266
Peter M. Worceshyn	JPL	(213) 354-5416 FTS 792-5416
Ron McPherson <u>or</u> Tsann W. Yu	NWS/NMC	FTS 763-8301

*CMDR. Jess Tupaz is official member.

TABLE VIII

RESPONSIBILITIES

SENSOR IMPLEMENTATION MANAGERS	ADWG/PDPS/ADF	EXPERIMENT TEAMS
* PROVIDE PRE-LAUNCH CALIBRATION DATA	DOCUMENT AND DISTRIBUTE CALIBRATION DATA	REVIEW CALIBRATION DATA
* DEFINE DATA REQUIRE- MENTS FOR ENGINEERING ASSESSMENT	DESIGN AND BUILD DATA SYSTEM FOR ENGINEERING ASSESSMENT	
REVIEW DATA SYSTEM SPECIFICATIONS	* DESIGN, BUILD, AND OPERATE DATA SYSTEM FOR SDR PRODUCTION - DISTRIBUTE ON REIMBURSABLE BASIS	REVIEW DATA SYSTEM SPECIFICATIONS
* PERFORM ENGINEERING ASSESSMENT	PROVIDE DATA PRODUCTS FOR ENGINEERING ASSESSMENT	REVIEW ENGINEERING ASSESSMENT REPORTS
PROVIDE INPUTS TO AND REVIEW HANDBOOK	* WRITE SDR USERS HANDBOOK	REVIEW HANDBOOK
REVIEW SPECIFICATIONS	* DESIGN, BUILD, AND OPERATE DATA SYSTEMS FOR ADR PRODUCTION	* PROVIDE SPECIFICATIONS FOR ADR

TABLE VIII (CONT'D)
RESPONSIBILITIES (CONT'D)

SENSOR IMPLEMENTATION MANAGERS	ADWG/PDPS/ADF	EXPERIMENT TEAMS
REVIEW SPECIFICATION	DESIGN, BUILD, AND OPERATE DATA SYSTEM FOR TDR PRODUCTION	PROVIDE SPECIFICATIONS FOR TDR
* DEVELOP SENSOR ALGORITHMS	DESIGN AND BUILD DEVELOPMENTAL AND PRODUCTION DATA SYSTEM WHICH INCORPORATES SENSOR ALGORITHMS	REVIEW AND APPROVE SENSOR ALGORITHMS
	DESIGN AND BUILD DEVELOPMENTAL AND PRODUCTION DATA SYSTEMS WHICH INCORPORATES GEOPHYSICAL ALGORITHMS	* DEVELOP GEOPHYSICAL ALGORITHMS
PROVIDE INPUTS TO ANALYSIS/EVALUATION PROCESSING SPECIFICATIONS	DESIGN AND BUILD DEVELOPMENTAL DATA SYSTEM FOR ANALYSIS/ EVALUATION PROCESSING	* DEVELOP ALGORITHMS AND SPECIFICATIONS FOR ANALYSIS/ EVALUATION PROCESSING AND DISPLAY. SPECIFY FORMAT AND SPECIFY FORMAT AND CONTENT OF INPUTS AND OUTPUTS

TABLE VIII (CONCLUDED)
RESPONSIBILITIES (CONCLUDED)

SENSOR IMPLEMENTATION MANAGERS	ADWG/PDPS/ADF	EXPERIMENT TEAMS
SUPPORT THE GEOPHYSICAL EVALUATION WITH EMPHASIS ON THE SENSOR ALGORITHMS PROVIDE INPUTS TO AND REVIEW HANDBOOK	PROVIDE DATA SYSTEM WITH REMOTE TERMINAL ACCESS TO PROGRAMS AND DATA PROCESS 2-3% (10-12 DAYS) OF MISSION DATA SET TO EXPERIMENT TEAM REQUIREMENTS. PERFORM ANALYSIS/EVALUATION PROCESSING AS REQUIRED. * WRITE A GDR USERS HANDBOOK * PRODUCE A COMPLETE MISSION SET OF GDR'S AND PROVIDE ONE COPY TO NOAA-EDS FOR FURTHER DISTRIBUTION	* PERFORM GEOPHYSICAL EVALUATION OF SENSORS AND ALGORITHMS. SUGGEST MODIFICATIONS PROVIDE INPUTS TO AND REVIEW HANDBOOK

TABLE IX

INTER-TEAM RESPONSIBILITIES

- SMMR TEAM PROVIDES PATH LOSS CORRECTION AND RAIN RATE TO SASS TEAM
- VIRR TEAM FURNISHES CLEAR/NOT CLEAR AND POTENTIAL RAIN CELL DETERMINATION TO SASS TEAM
- SMMR AND SASS TEAMS PROVIDE EACH OTHER WITH WIND MAGNITUDE ESTIMATES
- ALTIMETER TEAM PROVIDES ALTIMETER σ^0 VALUES.

APPENDIX
EXPERIMENTS

1. Black, Peter G. (NOAA-ERL) and Woiceshyn, Peter M. (JPL): "SASS/Geostationary Satellite/Aircraft Wind Analysis Comparisons and Evaluation of SASS Capabilities for Measuring Hurricane Wind Fields.
2. Halberstam, I. (JPL) M. Halem & Cane, Mark A. (GISS) Investigation of Possible Applications of SeaSat Data to Weather and Ocean Forecasting.
3. Krishen, K. & Others (NASA-JSC) "Vegetation Identification/Characteristics."
4. Krishen, K. & Others (NASA-JSC) "Snow Mapping Experiment."
5. Pierson, W. J. (CUNY) Extratropical Cyclones.
6. Pierson, W. J. (CUNY) Intertropical Convergence Zone.
7. Pierson, W. J. (CUNY) Sea Breeze and Monsoon Effects.
8. Pierson, W. J. (CUNY) Tropical Cyclones.
9. Pierson, W. J. (CUNY) Convergence, Divergence, and Wind Stress Gradients.
10. Moore, R. K. (U. of K CRES) Rain Effects on Wind Vector Determination
11. Moore, R. K. (U of K CRES) Atmospheric Attenuation Experiment.
12. Moore, R.K. (U of K CRES) Sea-Ice Measurement.
13. Moore, R. K. (U of K CRES) Antenna Pattern Measurement.
14. Moore, R. K. (U of K CRES) Regional Effects on the Radar Backscatter.
15. Moore, R. K. (U of K CRES) Effects of Small Ice Floes on Wind-Vector Determination.
16. Moore, R. L. (U of K CRES) General Radar Design Uses of SASS Return.
17. Moore, R. K. (U of K CRES) Monitoring Snow Overland.
18. Moore, R. K. (U of K CRES) SASS Soil Moisture Experiment.
19. Moore, R. K. (U of K CRES) Vegetation Monitoring.

APPENDIX

EXPERIMENT SUMMARIES

1. SASS/Geostationary Satellite/Aircraft Wind Analyses Comparisons and Evaluation of SASS Capabilities for Measuring Hurricane Wind Fields, by Peter G. Black (NOAA-ERL) and Peter M. Woiceshyn (JPL).

This experiment proposes use of hurricane ground truth and other data from aircraft support flights to validate SeaSat A surface wind measurements in a hurricane. Since 50 km resolution of SASS data is lower than desired in a hurricane, the high resolution modes (single pol. one side) and rotation of the satellite in azimuth by $\leq 45^\circ$ is requested over 3 to 6 selected hurricane passes is proposed as part of the SASS operations in support of this experiment. The SASS data obtained would be converted to surface winds which would be compared to data obtained from (1) Wind data which NOAA expects to be obtained from the SeaSat A altimeter data (2) Winds obtained using SUS scatterometer data (3) Insitu data obtained by surface truth and NOAA aircraft (4) Forecast data. These comparisons would be used to

- (1) Evaluate and update the SeaSat SASS and altimeter algorithms to produce winds in hurricanes

- (2) Determine feasibility of incorporating wind fields into synoptic and or dynamic hurricane prediction models, and developing such algorithms for data obtained from SeaSat.

- (3) Determine difference in forecast errors with and without SeaSat winds to measure their utility.

- (4) Implement and test real time acquisition of SeaSat data at NHC, Miami and orient users to its availability and usefulness.

During the 1978 tropical cyclone season winds will be derived by the GSFC Severe Storm Group from cloud motions determined from a series of geosynchronous satellite images and compared with simultaneously derived surface winds from the SeaSat-A scatterometer (SASS). Geosynchronous satellite images at 7.5 min intervals or less will be requested from the National Environmental Satellite Service (NESS) since it has been found that images at that frequency considerably improve the wind analysis over those made with images taken at longer intervals. Either the eastern or western SMS/GOES satellites will be used in order to cover cyclone possibilities in the Atlantic and/or Eastern Pacific.

The GSFC Severe Storms Group will produce selected wind field analysis from the geosynchronous satellite data for times that are concurrent with SeaSat passes over a cyclone. These would be compared with the winds that are provided to the group from the SASS. The wind fields from the separate and combined sources would then be tested in dynamical models to assess their impact on tropical cyclone predictability.

2. Investigation of possible applications of SeaSat data to weather and ocean forecasting, by I. Halberstram of NASA-JPL, M. Halem and Mark A. Cane of NASA-GISS.

As a part of the overall GISS program to investigate the possible applications of SeaSat data to weather and ocean forecasting, GISS intends to run the finished scatterometer algorithms with their own models as auxiliary input data. The major objective concerns processing all the data for the two FGGE special observation periods (Jan. and June 1979). These processed data will be used to (1) supply data for the GARP level II data set and (2) to conduct real forecast impact tests. Additional data will be processed during a

meteorologically interesting two week period during September/Oct. 1978 to check out GISS programs. During these periods all data needed as input to the SASS algorithms will be required at GISS. The data will not be required real-time, and minimum SASS resolution should exceed minimum GISS grid resolution of 250 km.

3. Vegetation Identification Characteristics, by K. Krishen and co-investigators-NASA JSC.

All of the SeaSat A sensors will be studied for their usefulness in studying crops, range, and forest areas. Primary interest will center on SAR because of its 25 km resolution. The SASS σ^0 data supported with VIRR, SMMR and ALT data, will be examined for correlating with vegetation type and density. These data will be compared to surface truth and aircraft 13.36 GHz scat and photography data will also be registered to Landsat data and the joint multisensor possibilities for classification improvement evaluated. The following objectives are listed:

(1) Evaluate of the applicability of SASS data for vegetation identification and estimation of vegetation characteristics.

(2) Provide inputs to the SAR soil moisture program to account for affect of soil masking.

(3) Study directional effects on classification of crops (row and wind) since SASS provides directional data.

A total of 12 summer passes over 3 selected sites are requested.

4. Snow mapping experiment, by K. Krishen & Co. investigators of NASA JSC.

SeaSat-A SASS data will be studied for potential in monitoring and measuring the extent and depth of snow cover in watersheds where such

information is invaluable in predicting floods that results from spring snow melts. The test sites consist of mountainous areas including the Central Sierras, Steamboat Springs Colo., and the Wind River Mountains, and plains areas including Luverne, Minnesota, and the upper Missouri River basin. SeaSat SASS and L-Band SAR, SMMR and ALT data will be coordinated with ground truth and A/C 6 GHz and 13.3 Scatterometer and photography to assess the capability of the satellite for monitoring snow cover, snowpack moisture content, and liquid water content. 10 passes in late winter/early spring are required at these sites 2 times per site per year.

5. Extratropical Cyclones, by W. J. Pierson of CUNY.

Extratropical cyclones in the winter hemisphere will be the prime subject of study since they are an ever present feature of middle latitude weather poleward of the subtropical highs. The determination of the wind fields around them should be an aid in finding the centers of the lows associated with them and what their central pressures are.

6. Intertropical Convergence Zone, by W. J. Pierson of CUNY.

The Intertropical convergence zone separates the NE Trades of the Northern Hemisphere from the SE Trades of the Southern Hemisphere. This zone is characterized by heavy cumulus activity, and it shifts north and south seasonally. Its location and movement can be studied with the SASS.

7. Sea Breeze and Monsoon Effects, by W. J. Pierson of CUNY.

Space Photographs of the Indian Subcontinent have shown a sea breeze (or perhaps a monsoon effect) that extends hundreds of kilometers over the ocean from the land. The change in winds in this area can be studied.

8. Tropical Cyclones, by W. J. Pierson of CUNY.

Several of the scanning modes are ideal for the study of the strong horizontal gradients in the wind fields around these tropical systems.

9. Convergence, Divergence, and Wind Stress Gradients, by W. J. Pierson of CUNY.

For the first time sufficient highly accurate wind fields can be obtained that suggest that fields of horizontal divergence and convergence along with associated vertical motions can be computed for the planetary boundary layer. The stress of the sea surface can also be used to calculate local areas of strong upwelling.

10. Rain Effects on Wind Vector Determination, by R. K. Moore, U of Kansas.

Rain may effect up to 10% of the SASS observations in some areas. In particular, for winter storms in the North Atlantic, tropical storms, and hurricanes, the consideration of rain effects is important. The University of Kansas proposes to use SASS and SMMR measurements within range of shore-based meteorological radar and near a data buoy to determine the effect of rain drops striking the water on radar backscatter from a wind-driven sea. This will help to establish rain rates at which the correction must be made to the wind-vector algorithms, the size of the correction, and rain rates for which the SASS observations are no longer useful for wind-vector determination. This program will also include theoretical development of the radar backscatter from the interaction of wind- and rain-generated waves. The additional support of three SASS underflights in and adjacent to rain cells flown at multiple altitudes and for different rain rates would be useful in creating a well defined data bank for comparisons with satellite results.

11. Atmospheric Attenuation Experiment, by R. K. Moore, U. of Kansas.

An experiment should be performed using two upward looking radiometers, preferably at 10.69 and 14.6 GHz, to verify the SMMR observations and estimated atmospheric attenuation at the SASS frequencies. The present models for the atmospheric attenuation are based upon radiative transfer theory extended to the case of a downward looking radiometers. The validity of this theory for the downward looking radiometer has never been experimentally verified. However, good agreement between theory and experiment have been obtained for the upward looking radiometers. This experiment should be performed during the Geophysical Evaluation period of the Seasat experiment so the results can be entered as soon as possible into the SASS algorithm. The location should be near sources of both sea truth and weather information. For example, the radiometers could be mounted on the Chesapeake Bay light tower, though the optimum location would be well-off-shore oil production platform in the North Sea where cloudy and rainy conditions persist year round.

12. Sea-Ice Measurement, by R. K. Moore, U of Kansas.

Approximately ten percent of the sea surface is covered by ice at least part of the year. The University of Kansas proposes a special case study using both SASS and SMMR to evaluate the merits of the coarse-resolution active and passive sensors for ice monitoring. Data at 13.3 GHz from the NASA Earth Resources Aircraft Program demonstrated that Ku-band scatterometers can discriminate ice from open water, and also, at large incidence angles, different classes of first-year ice and first-year ice from multi-year ice. To evaluate the performance of the SeaSat instruments for ice monitoring, Landsat images will be used to provide

ground truth when lighting conditions permit. During dark periods, Nimbus or NOAA-5 IR images will be necessary to provide the ground truth.

13. Antenna Pattern Measurement, by R. K. Moore, U of Kansas.

Knowledge of the performance of the SASS antenna is essential for proper analysis and use of the data obtained by the instrument. The shape of the pattern is necessary in the algorithm to generate values of the scattering coefficient from the received signal. The pointing direction of the antenna is the main factor in determining the position of the cells on the earth's surface. This is important both for location purposes and to verify that overlap occurs between forward and aft antenna beams as planned. The value of such inflight measurement of the pattern was demonstrated on SKYLAB when the scanning mechanism failed and the antenna was damaged while repairing the mechanism. The first indications of problems with the antenna came from the ground experiment, which also provided useful information that aided in determining what sort of failure had occurred. With the SASS this problem may be even more important because the antennas must be deployed with the consequential danger of both damage to the antenna and errors in the planned pointing direction.

This experiment proposes to measure the antenna patterns of the SASS by setting upon array of calibrated ground-based antennas over an area large enough to determine the shape and peak of the pattern. The method of obtaining the data assumes setting the array of antennas in a line perpendicular to the flight path and observing the fan pattern at each location. The complete pattern could be developed in this manner after a large number of satellite passes, or by using several columns of receivers. Since the fan

beam is oriented 45° with respect to the flight path, the measurements and calibrations have to be correlated to remove time differences for the method. A second and better method is to rotate the spacecraft 45° and set up a denser array of antennas across the ground track so that the shape can be monitored as a function of elevation angle with one set of antennas.

14. Regional Effects on the Radar Backscatter, by R. K. Moore, U of Kansas

The radar return from the sea could vary due to regional effects. In warm waters there is no reason to suspect that the return will vary regionally. On the other hand, in polar regions the viscosity of the water increases as the temperature approaches freezing, forseably affecting the capillary region of the sea spectrum, and thus the radar return. Less important geographically, but also worth investigating, are areas such as the Sargasso Sea, where large amounts of floating vegetation are expected to modify the radar backscatter. Both SASS and underflight observations should be made in such areas to establish these potential effects on the wind estimates.

15. Effect of Small Ice Floes on Wind-Vector Determination, by R.K. Moore, U of K

Ice floes cover much of the sea in areas like that south of Greenland during certain times of the year. This is likely to seriously hinder the wind-vector measurement. The University of Kansas proposes to use SASS, SMMR, and SAR data in a region near Greenland to the southern extent of the ice floe field during the summer of 1978 and spring of 1979 to develop a method to compensate for the ice floes or determine a method to detect these conditions so that they can be excluded from wind-vector algorithms. During the early stages at least, Landsat data will be needed until the value of the SAR as a source of surface truth is determined. Also, the

additional support of a photographic underflight across the boundary of the floating ice up to the boundary of the pack would serve as a check on the surface truth evaluation.

16. General Radar Design Uses of SASS Returns, by R. K. Moore, U of K

SASS experiments over land should generate a large data base of scattering coefficients for angles of incidence between 25° and 65° . These returns can be combined to generate a curve of the median scattering coefficient over this range of incidence angles. Also, the range of values exceeded various percentages of the time could be generated. These results provide data useful in the design of radars, especially as they apply to clutter models to the preprocessing dynamic range of spaceborne SARs, and to specialized radars (such as Doppler velocimeters).

17. Monitoring Snow Overland, by R. K. Moore, U of K

Special case studies proposed by the University of Kansas for overland geophysical use will include analysis to identify the potential of coarse resolution sensors to map snow conditions in mountain areas and in the plains. Data taken by the University of Kansas with a variety of active and passive microwave sensors near Steamboat Springs, Colorado, during the 1976-1977 winter, showed snow wetness was the most influential snow parameter on active and passive microwave measurements for snow 50 cm thick. When no changes in snow wetness occurred, the sensors displayed an almost linear response to the snow water equivalent. For deeper snow, other factors may also be important. A coarse-resolution sensor such as SASS may be particularly useful for run-off and early-season agricultural soil-moisture forecasts.

18. SASS Soil-Moisture Experiment, by R. K. Moore, U of K

Overland geophysical use of SASS will include an experiment to determine the potential of coarse-resolution microwave sensors to monitor soil moisture. While the optimum frequencies to monitor soil moisture appear to be 4-5 GHz, earlier experiments with the 13.3 GHz scatterometer indicate that Ku-band sensors could be effective during late fall to early spring. The SKYLAB active and passive experiments at 13.9 GHz, however, did show poor correlation with soil moisture. This performance was attributed to poor ground truth. The size of the SKYLAB resolution cell, 20 km, was such that it was necessary to interpolate sparsely measured APIs with many cells containing no measurements at all. For the SeaSat, with its much larger resolution cell, this problem should be greatly reduced, and its greater coverage should permit concentration on cells where adequate ground truth is available.

19. Vegetation Monitoring, by R. K. Moore, U of Kansas CRES.

The frequency of the SASS has been demonstrated as almost the optimum for time-sequential determination of the type of crop growing in a farmer's field (1). Unfortunately, however, the resolution of SASS is too coarse to permit testing of the ability of the spacecraft radar to determine the type of crops planted. Resolution may be adequate, however, to allow development of a time-sequential discrimination capability for the type and health of rangeland, forests, and other natural vegetation that grows in large homogeneous patches, and (perhaps) in large single-crop agricultural areas like the wheat land in North Dakota. The Skylab S-193 scatterometer was able to distinguish among types of vegetation in Brazil where the land units are large, even without having the opportunity for time-sequential measurement. This

capability should be retested in Brazil, using time sequences, but the time sequences are probably much more valid in the temperate region where growth starts from essentially zero in the spring rather than in the tropics where growth variation is less extreme and is tied more to the rainfall cycle and flooding cycle than to the drying up of plants in the winter.

Test sites must be established where adequate ground comparison can be made between the progress of vegetation, the type of vegetation, and its distribution. Because of the large resolution of the SASS, the vegetation-type distribution for large areas can be determined from existing vegetation maps and areas where suitable maps are available will be selected for testing the hypothesis that one can distinguish the vegetation types with such a broad resolution sensor. The progress of the vegetation must be monitored with some actual measurements made on the ground. A few areas will be selected where the vegetation is sufficiently homogeneous within a resolution cell so that the measured scattering will be representative of that class of vegetation. The cells selected will have different types of vegetation so that the effects of the different growth cycles can be factored in. This experiment will allow deciding whether it is possible to keep track of the different classes of vegetation and their progress in remote parts of the world. The resolution is too poor to be of value in the U.S.

Ref.: Bush, T.F., and F. T. Ulaby, "Crop Classification with Radar: Preliminary Results," RSL Technical Report 330-1, October, 1976. Supported by NASA Contract NAS 9-15003.

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16. Abstract This plan has been generated by the SeaSat-A Satellite Scatterometer (SASS) Experiment Team to define the pre and post-launch activities necessary to conduct sensor validation and geophysical evaluation. Details included are an instrument and experiment description/performance requirements, success criteria, constraints, mission requirements, data processing requirement and data analysis responsibilities. It is intended that this plan be updated as required to reflect the evolving nature of the Experiment. Proposed changes to the plan shall be submitted to the SASS Experiment Team in care of Dr. W. Linwood Jones (LaRC) for team discussion and consensus, and shall be implemented as addendums only after formal approval/concurrence by the signatories to the document.					
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